IRENA
International Renewable Energy Agency

Renewable Energy and Jobs
Annual Review 2019

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ABOUT IRENA

The International Renewable Energy Agency (IRENA) is an intergovernmental organisation that supports countries in their transition to a sustainable energy future and serves as the principal platform for international co-operation, a centre of excellence, and a repository of policy, technology, resource and financial knowledge on renewable energy. IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy, geothermal, hydropower, ocean, solar and wind energy, in the pursuit of sustainable development, energy access, energy security and low-carbon economic growth and prosperity.

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IRENA HEADQUARTERS

Masdar City

P.O. Box 236, Abu Dhabi, United Arab Emirates

www.irena.org

MESSAGE FROM THE IRENA DIRECTOR-GENERAL

Renewable energy delivers on all main pillars of sustainable development: environmental, economic and even social. Alongside declining costs and steadily improving technologies, the transition to renewables is also creating numerous employment opportunities.

Beyond pursuing climate goals, many governments have prioritised renewables as a driver of low-carbon economic growth. Diversification of the supply chain has broadened the sector's geographic footprint beyond a few leading markets, as more countries link sustainable technology choices to broader socio-economic benefits. Increasingly, countries envisage a domestic renewable energy industry taking the place of unsustainable fossil-based industries.

The sector now employs at least 11 million people worldwide, with more countries manufacturing, trading and installing renewable energy technologies every year. As the global energy transformation continues to gain momentum, this employment dimension ensures socio-economic sustainability and provides yet another reason for countries to commit to renewables.

Francesco La Camera
Director-General
International Renewable Energy Agency

IRENA
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Key Numbers

11 million jobs in 2018

39 % of all renewable energy jobs are in China

3.6 million jobs are in the solar PV industry

32 % of renewable energy jobs are held by women

KEY FACTS

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- The global renewable energy sector employed 11 million people in 2018. This compares with 10.3 million in 2017, based on available information.
- Employment remains concentrated in a handful of countries, with China, Brazil, the United States, India and members of the European Union in the lead. Asian countries' share remained at 60% of the global total.
- Several factors — including national deployment and industrial policies, changes in the geographic footprint of supply chains and in trade patterns, and industry consolidation trends — shape how and where jobs are created.
- Nonetheless, the increasingly diverse geographic footprint of energy-generation capacities and, to a lesser degree, assembly and manufacturing plants, has created jobs in a rising number of countries.
- The solar PV industry retains the top spot, with a third of the total renewable energy workforce. In 2018, PV employment expanded in India, Southeast Asia and Brazil, while China, the United States, Japan and the European Union lost jobs.
- Rising off-grid solar sales are translating into growing numbers of jobs in the context of expanding energy access and spurring economic activities in previously isolated communities.
- Rising output pushed biofuel jobs up 6% to 2.1 million. Brazil, Colombia, and Southeast Asia have labour-intensive supply chains, whereas operations in the United States and the European Union are far more mechanised.
- Employment in wind power supports 1.2 million jobs. Onshore projects predominate, but the offshore segment is gaining traction and could build on expertise and infrastructure in the offshore oil and gas sector.
- Hydropower has the largest installed capacity of all renewables but is now expanding slowly. The sector employs 2.1 million people directly, three quarters of whom are in operations and maintenance.
- While the analysis suggests job growth in 2018, some of the increase reflects the continued improvement and refinement of methodologies that allows a rising share of employment to be captured in statistics.

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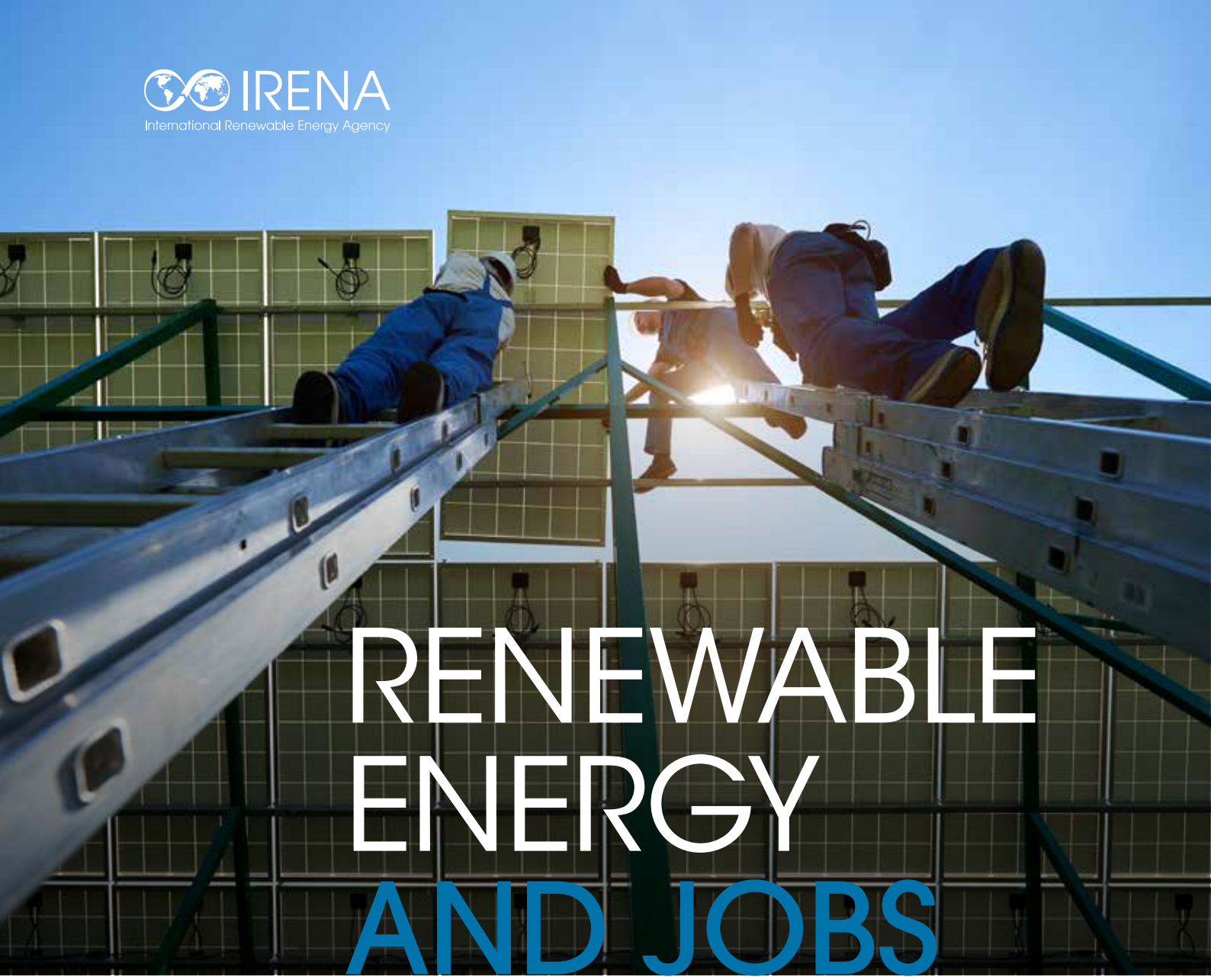


RENEWABLE ENERGY AND JOBS

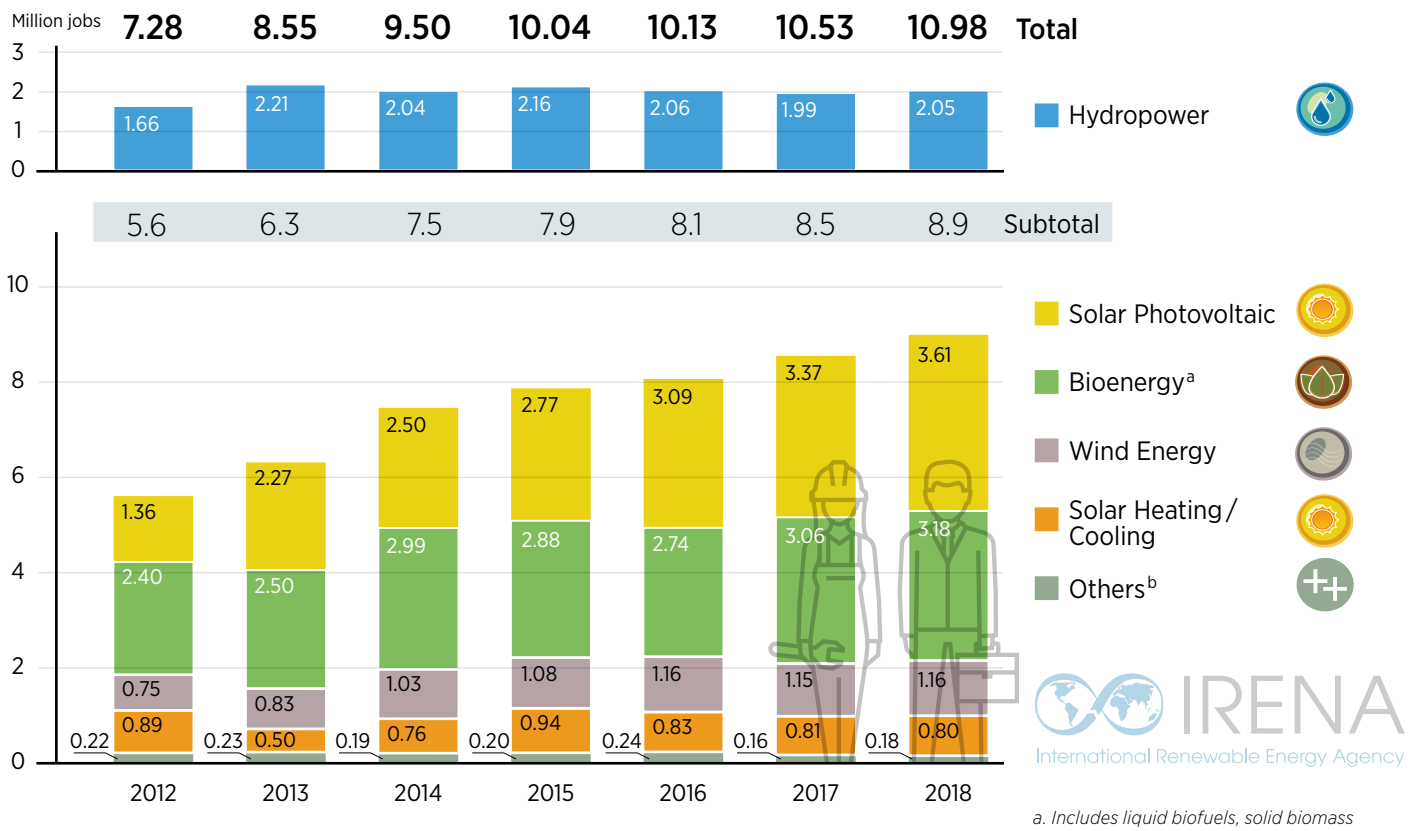
Annual Review 2019

The renewable energy sector employed at least 11 million people, directly and indirectly, in 2018.[1] The total includes, for the first time, a fuller estimate of off-grid solar in parts of the developing world. Renewable energy employment has continued to grow worldwide since the first annual assessment by the International Renewable Energy Agency (IRENA) in 2012. The solar photovoltaics (PV), bioenergy, hydro, and wind power industries were the biggest employers (Figure 1).

This sixth edition of *Renewable Energy and Jobs – Annual Review* provides the latest available estimates and calculations on renewable energy employment. It represents an on-going effort to refine and improve data and methodologies. Global numbers are based on a wide range of studies with varying methodologies and uneven detail and quality.

1 Data are principally for 2017 – 2018, with dates varying by country and technology, including some instances where only earlier information is available. The data for hydropower include direct employment only; the data for other technologies include both direct and indirect employment where possible.

FIGURE 1: **GLOBAL RENEWABLE ENERGY EMPLOYMENT BY TECHNOLOGY, 2012-2018**



Source: IRENA jobs database.

Note: Except for hydropower where a revised methodology led to revisions of job estimates, numbers shown in this figure reflect those reported in past editions of the Annual Review.

a. Includes liquid biofuels, solid biomass and biogas.

b. Other technologies include geothermal energy, concentrated solar power, heat pumps (ground-based), municipal and industrial waste, and ocean energy.

The first section of this report discusses key factors shaping renewable energy employment. This is followed by observations on job quality and inclusiveness, with Box 1 focused on gender. The third section highlights the latest employment trends in the modern energy context by technology. The fourth section presents a discussion of employment in off-grid solar for energy access. The fifth section offers insights for selected regions and countries; countries are listed in order of their jobs, installations or market size, rather than alphabetically. The report wraps up with a brief discussion of IRENA's ongoing work on the socio-economic impacts of renewable energy.

FACTORS SHAPING RENEWABLE ENERGY EMPLOYMENT

Several factors shape how and where employment is generated along the renewable energy supply chain. These include governmental policies; the diversification of supply chains; trade patterns; and industry reorganisation and consolidation trends. Aside from these factors, which are discussed below, labour productivity grows in importance over time. As renewable energy industries become more mature, gain economies of scale, navigate learning curves and turn more to automated processes, fewer people will be needed for a given task.

Governmental Policies

Governmental measures, such as auctions, feed-in tariffs, subsidies, and industrial, labour and trade policies, are indispensable as the renewable energy sector expands and matures. They thus retain strong influence on employment prospects.

Feed-in tariffs were essential to the creation of many of today's markets, but if their rates are too generous they can become a budgetary burden. The growing embrace of auctions in recent years has translated into lower project costs, greater competitiveness with fossil fuels, and thus more deployment. But the competitive pressure of tenders also entails risks. Winning bids may not always come to fruition. Cost pressure may lead some firms to use inexpensive but low-quality equipment, or to skimp on staffing levels, wages or skills-training (IRENA, IEA and REN21, 2018; IRENA, 2017a)

Above all, policymaking needs to minimise swings from strong supportive measures to aggressive curbs. Likewise, prolonged periods of policy uncertainty can trigger job loss if they lead equipment manufacturers, project developers, and other industry actors to mothball or shutter facilities.

Industrial policies leverage capabilities within an economy and strengthen domestic supply chains (IRENA, 2017b; 2017c; 2018). Well-designed incentives are needed to nurture nascent industries, along with preferential access to credit, economic incubators and supplier development programmes, as well as appropriate education, training and labour market policies to build a capable workforce. The proper policy mix – between enabling measures and mandates, and between inviting foreign investment and building domestic capabilities–needs to be tailored to country- or region-specific circumstances (IRENA, IEA and REN21, 2018)

A key example of a successful industrial policy is the well-developed domestic supply chains and economies of scale in China's solar PV industry. Manufacturing clusters in the Yangtze River Delta play a key role. The area's extensive industrial infrastructure, low power prices, and presence of suppliers from sectors such as the glass industry enables solar firms to purchase primary and intermediate inputs inexpensively. Strong support from central, provincial and municipal governments has been critical. Many other countries could, in principle, imitate such policies in order to build viable domestic supply chains (Ball *et al.*, 2017).

Trade, Supply-Chain Dynamics and Industry Consolidation

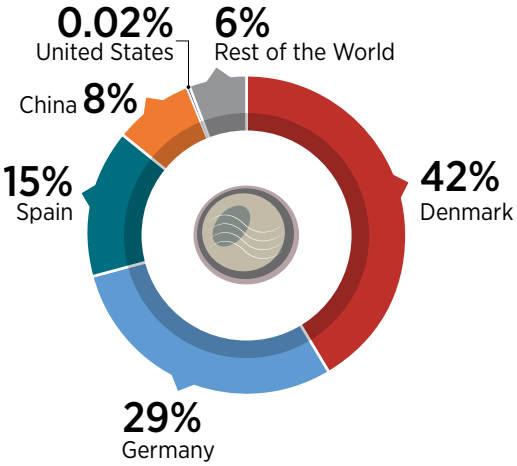
Domestic installation markets are important for employment generation in the downstream segments of the value chain. Deeper domestic supply chains translate into a lower degree of reliance on imports of equipment and components. On the other side of the equation, however, export sales hold great significance for job creation in countries that serve as regional or global manufacturing hubs. This is particularly true for China and a number of European countries (EurObserv'ER, 2019).

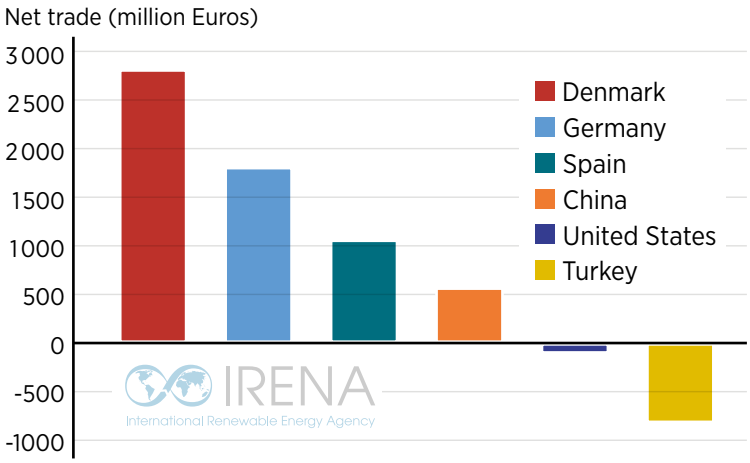
Countries' trade profiles vary considerably from one renewable energy technology to another (see Figure 2). For example, while China is the largest exporter in the field of solar PV, its wind power firms mostly serve their domestic market (BNEF, 2019). By contrast, Europe is a net importer of solar PV equipment, but the continent's wind sector (especially in Denmark, Germany, and Spain) is heavily export-oriented, and European wind firms also have an extensive international manufacturing footprint. The United States is a minor exporter of wind equipment and runs a very small negative trade balance in the sector, but is a large net solar importer along with India and Turkey (EurObserv'ER, 2019).

In biofuels, the United States accounted for close to 30% of exports in 2016, ahead of European countries (principally the Netherlands, France, Belgium, Hungary, Germany and the United Kingdom). In hydropower, China represented a quarter of global exports, while European firms (primarily based in Germany, Austria, and Italy) commanded a 46% share. The United States and India contributed just under 5% each.

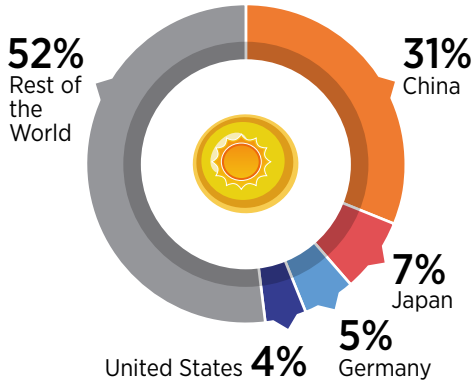
FIGURE 2: SHARE OF GLOBAL EXPORTS AND NET TRADE VALUES IN THE WIND AND SOLAR PV SECTORS FOR SELECTED COUNTRIES, 2016[2]

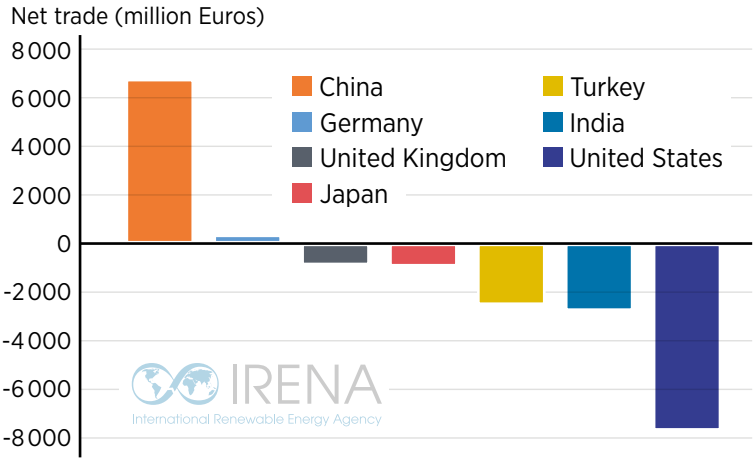
WIND





SOLAR PV





Source: EurObserv'ER, 2019.

Changes along renewable energy supply chains alter the industry's geographic footprint and its trade patterns, with consequences for where jobs are created and lost. Corporate strategies are a key driver, although some countries have sought to take an active role through local content requirements.

The footprint of the solar PV industry, for instance, has changed significantly since 2012. The bulk of manufacturing capacity has shifted to Asia, which now accounts for 92% and 85% of global cell and module capacities, respectively[3]. While China remains dominant, a number of Southeast Asian countries have emerged as significant exporters (Roselund, 2018). By contrast, the United States, India and Europe rely heavily on imports. In an effort to build or retain a domestic manufacturing base, some importing countries have adopted a variety of import tariffs and levies, but the effectiveness of such policies can vary (Trendforce, 2019; Gupta, 2018a).

2 Based on UN COMTRADE data. The year 2016 was chosen because the available 2017 data do not cover China.

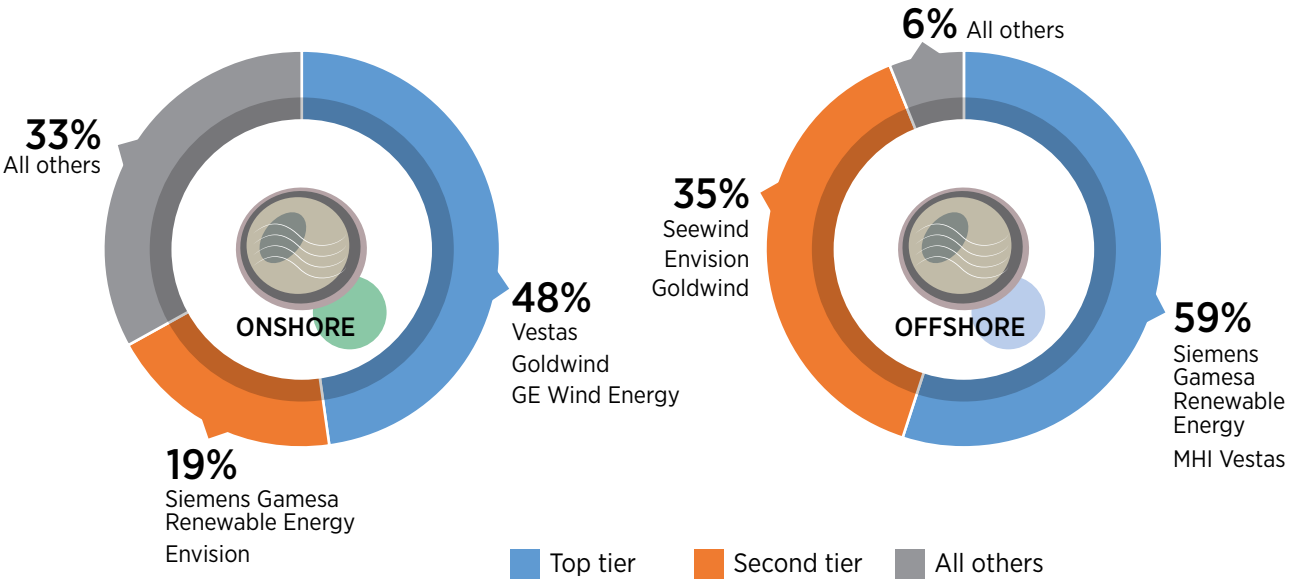
3 Not including India.

In the face of intensifying competitive pressures, industry consolidation is changing the face of the renewable energy sector. In wind power, for example, Siemens and Gamesa merged; Mitsubishi Heavy Industries and Vestas formed an offshore joint venture (MHI Vestas); and GE bought Alsthom's wind assets and acquired Denmark's LM Wind Power.

Just three companies (Vestas, GE and Siemens Gamesa) have dominated the US installation market in recent years (BNEF and BCSE, 2019). GE and Siemens Gamesa together control about half of the Brazilian market. Just five turbine manufacturers accounted for two thirds of all onshore wind turbines commissioned globally during 2018: Vestas (Denmark), Goldwind (China), GE (United States), Siemens Gamesa (Germany and Spain), and Envision (China) (see left-hand chart of Figure 3).

In the offshore segment, Siemens Gamesa and MHI Vestas are the undisputed global leaders with a combined 59% share in 2018, followed by three Chinese companies (Sewind, Envision, and Goldwind) that hold a combined 35% share (see right-hand chart of Figure 3). In Europe, just two firms accounted for 93% of cumulative offshore turbine installations as of the end of 2018: Siemens Gamesa (69%) and MHI Vestas (24%) (Wind Europe, 2019a).

FIGURE 3: **MARKET SHARES, ONSHORE AND OFFSHORE WIND, 2018**



Source: Wood Mackenzie, 2019.

Quality and Inclusion

As important as it is to shed light on the quantity of jobs created in renewable energy, job quality must be examined as well. Although detailed information remains quite limited, job quality is a critical aspect. A well-paying job that requires well-honed skills and is performed in a safe, rewarding workplace is a greater multiplier of socio-economic benefits than one that pays little, carries few benefits, or is temporary. Employment also needs to be inclusive, providing opportunities for people with different talents and skills, and ensuring that no population group, such as women, is systematically excluded. IRENA has emphasised the importance of gender equity in particular (see Box 1).

What makes for good jobs? The International Labour Organization (ILO, n.d.) defines "decent work" as work that is "productive and delivers a fair income, security in the workplace and social protection for families, better prospects for personal development and social integration, freedom for people to express their concerns, organize and participate in the decisions that affect their lives and equality of opportunity and treatment for all women and men".

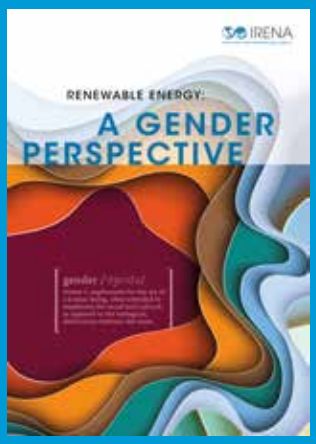
As is true for the economy at large, job quality in renewable energy varies widely across the industries and companies that make up the sector and its diverse supply chain. Variations in required skills and occupational patterns explain some of this. The significant role of the agricultural supply chain gives bioenergy a very different profile from the solar, wind, hydropower, and geothermal industries.

With respect to issues like wage levels and workplace protections, national regulations can make a big difference, as can corporate management culture and the presence of labour representatives. A friendly workplace tends to minimise staff turnover rates and is more likely to yield high-quality performance in equipment manufacturing, construction and installation, and operations and maintenance.

BOX 1. ENGENDERING THE ENERGY TRANSITION

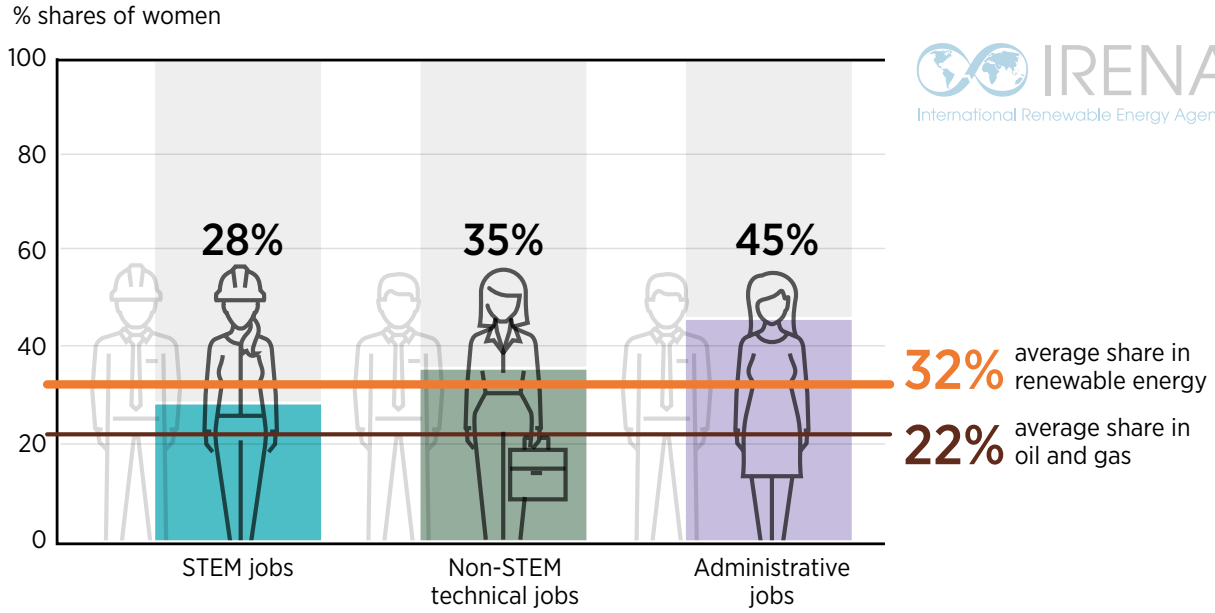
The global shift to renewables demands a growing array of skills – technical, business, administrative, economic and legal, among others. Widening the talent pool is thus a pragmatic reason for boosting the participation of women in renewable energy, coming on top of considerations of greater gender equity and fairness.

Over the years, IRENA has addressed the gender dimension of renewable energy in multiple publications and programmatic activities to help fill the knowledge gap in this field. Based on an in-depth literature review and a ground-breaking survey of over 1 400 employees, companies and institutions, *Renewable Energy: A Gender Perspective* (IRENA, 2019a) contributed to a better understanding of challenges and opportunities at the intersection of gender and renewable energy.



The report found that because of its multi-disciplinary dimension, the renewable energy field appeals to women in ways that the fossil fuel industry does not. Women currently represent 32% of the renewable energy workforce, substantially higher than the 22% average reported for the global oil and gas industry (see Figure 4). The finding is consistent with national level surveys. In the United States, for example, the share of women among all solar workers has risen from about 19% in 2013 to 26% in 2018 (Solar Foundation, 2019).

FIGURE 4: SHARES OF WOMEN IN STEM, NON-STEM AND ADMINISTRATIVE JOBS IN RENEWABLE ENERGY



Source: IRENA, 2019b.

STEM = science, technology, engineering and mathematics.

Yet, much remains to be done to boost women's participation, ease their entry into the industry, and improve their career prospects to allow their talents to be fully utilised. At 28%, women's presence in science, technology, engineering and mathematics (STEM) jobs is far lower than in non-STEM positions (35%) and administrative jobs (45%).

IRENA survey respondents highlighted barriers that prevent women from entering the workforce and advancing in their careers – prominent among them social and cultural norms, prevailing hiring practices, a lack of relevant skills, lack of awareness of job opportunities and lack of access to professional networks.

A persistent glass ceiling remains the most significant barrier to retention and career advancement. In close to half of the private sector organisations participating in the survey, at least three-quarters of board members are men. Other challenges relate to the lack of a supportive environment, such as flexible work hours, family-friendly measures, mentoring, networking, training opportunities and gender equity targets.

Wage inequalities were flagged as an issue as well, with close to two-thirds of respondents expressing the view that women in renewable energy earn less than men for the same position. The remaining third believe that men and women are paid equally.

In the access context (*i.e.*, where modern energy services are limited or non-existent), decentralised renewable energy solutions offer tremendous opportunities for women's engagement in multiple segments of the value chain. Here, too, however, barriers exist: cultural and social norms, the lack of gender-sensitive programmes and policies, insufficient skills and training opportunities, inequity in ownership of assets, and lack of access to finance. For example, a study of the Indian solar rooftop sector found that women accounted for just 11% of the workforce (a low share, but higher than women's presence in the country's fossil fuel sector). Segments of the solar value chain where office-based occupations predominate (design and pre-construction) attract women much more than construction or operations and maintenance (Nobuoka, Patnaik, Jha and Kuldeep, 2019).

Gender diversity in renewable energy can be substantially improved in both the modern and access-deprived contexts by action at several levels:

- Mainstreaming gender in policy design and project implementation, backed by solid disaggregated data gathering and monitoring;
- Tailoring training and skills, a task requiring government coordination of all actors;
- Implementing policies to attract and retain talent and thereby ensure a supportive environment in the workplace;
- Supporting women to become agents of change and to challenge cultural and social norms in their environment;
- Unlocking new livelihood opportunities in the access context, such as financing and market entry. Beyond gender-sensitive changes in the renewable energy sector, social and economic policies must address legal and social barriers that limit women's education, asset and land ownership and access to credit.

In 2019, IRENA will present a new report based on ground-breaking primary data on how large-scale solar and wind projects in Sub-Saharan Africa can benefit women in rural communities (IRENA, 2019c forthcoming).

Adapted from IRENA, 2019a

RENEWABLE ENERGY EMPLOYMENT BY TECHNOLOGY

This section highlights employment trends by technology (Figure 5). It discusses employment in solar PV, liquid biofuels, wind, solar heating and cooling, and hydropower. The remaining renewable energy technologies — biogas, geothermal energy and ground-based heat pumps, CSP, waste-to-energy, and ocean or wave energy — employ far fewer people, and less information is available for them.

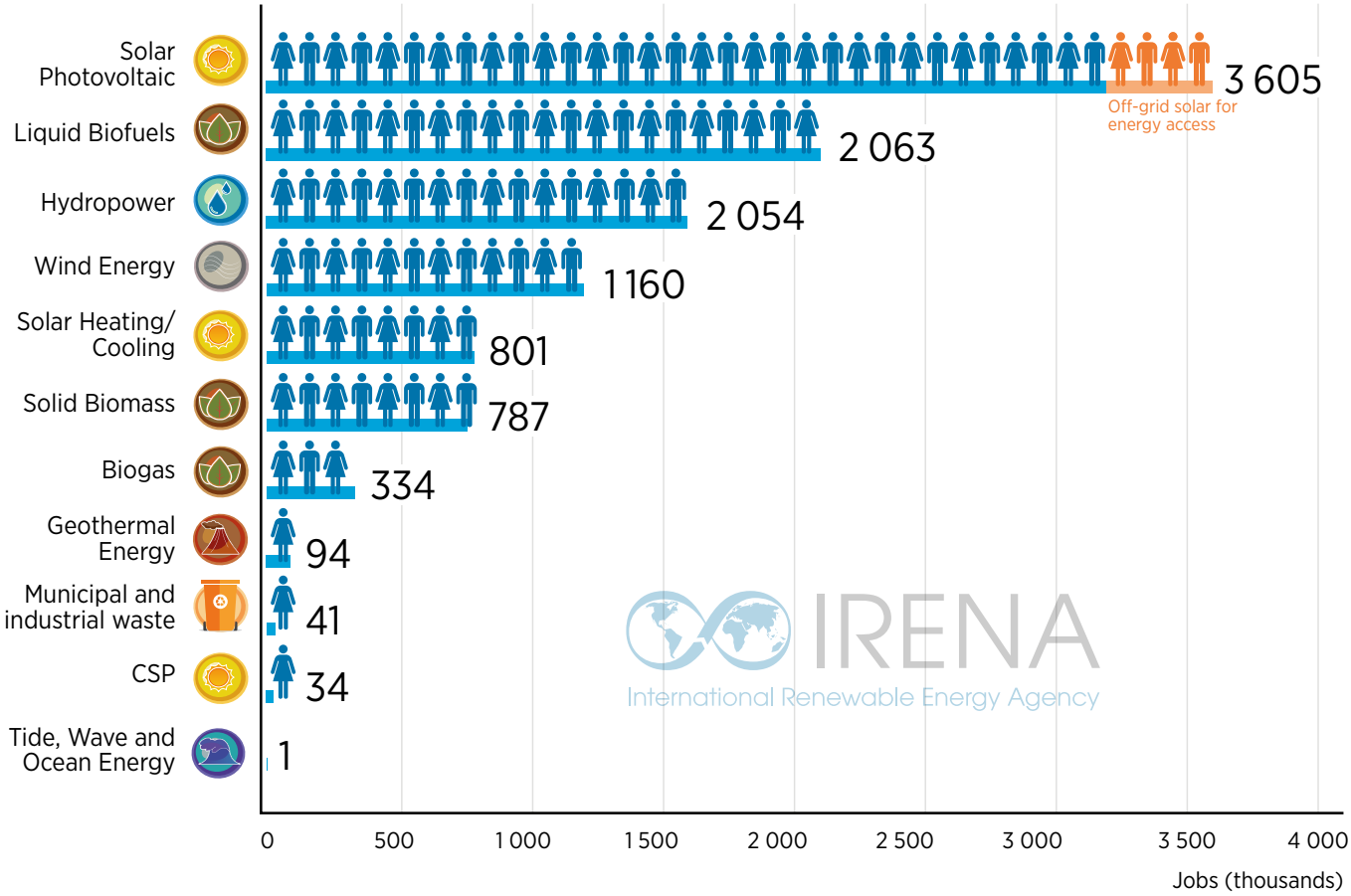
SOLAR PHOTOVOLTAICS

Globally, the solar PV industry installed 94 gigawatts (GW) of capacity during 2018, the same amount as in 2017. China, India, the United States and Japan were the most important installation markets, followed by Australia, Germany, the Republic of Korea, and Turkey (IRENA, 2019b).

A recent listing reveals that 50 leading solar PV panel manufacturers maintain factories in 23 countries (Solar Power World, n.d.). China remains dominant, accounting in 2018 for 69% and 64% of global cell and module capacities, respectively. All Asian countries as a group (excluding India) held shares of 92% and 85%, respectively (Trendforce, 2019). Japan, the Republic of Korea, and Chinese Taipei are important producers. Driven by Chinese and other foreign investment, Malaysia, Thailand and Viet Nam are playing significant roles as producers and exporters[4]. Viet Nam hosts

4 Module manufacturing capacities are 7.2 GW in Viet Nam, 6.5 GW in Malaysia, and 1.8 GW in Thailand (Beetz, 2018a).

FIGURE 5: **RENEWABLE ENERGY EMPLOYMENT BY TECHNOLOGY**



Source: IRENA jobs database.

Note: Another 7600 jobs, not shown separately here, cannot readily be broken down by individual renewable energy technology.

facilities owned by 11 different manufacturers; Malaysia, 9; and Thailand, 6 (Solar Power World, n.d.).

IRENA estimates that global solar PV employment stood at 3.6 million jobs in 2018[5]. Of the leading ten countries shown in Figure 6, eight are Asian (for the purposes of this report, Turkey is counted as part of Asia). Overall, Asia is home to almost 3 million solar PV jobs (85% of the global total), followed by North America's 6.4% share, Africa's 3.9% and Europe's 3.2%. This year's global total is not directly comparable to the figure reported in last year's edition. It includes an off-grid jobs estimate of 372 000 jobs for South Asia and parts of Africa (see the section on "Renewable Energy Employment: Focus on Access" further below). Earlier editions did not have fully comparable estimates for these regions.

China, the leading producer of PV equipment and the world's largest installation market, accounted for about two-thirds of PV employment worldwide, or some 2.2 million jobs (CNREC, 2019). A strong pace of capacity additions in India (9.2 GW in 2018) led IRENA to raise its on-grid solar employment estimate from 92 400 jobs to 115 000 jobs, a number that could double if off-grid deployments were included.

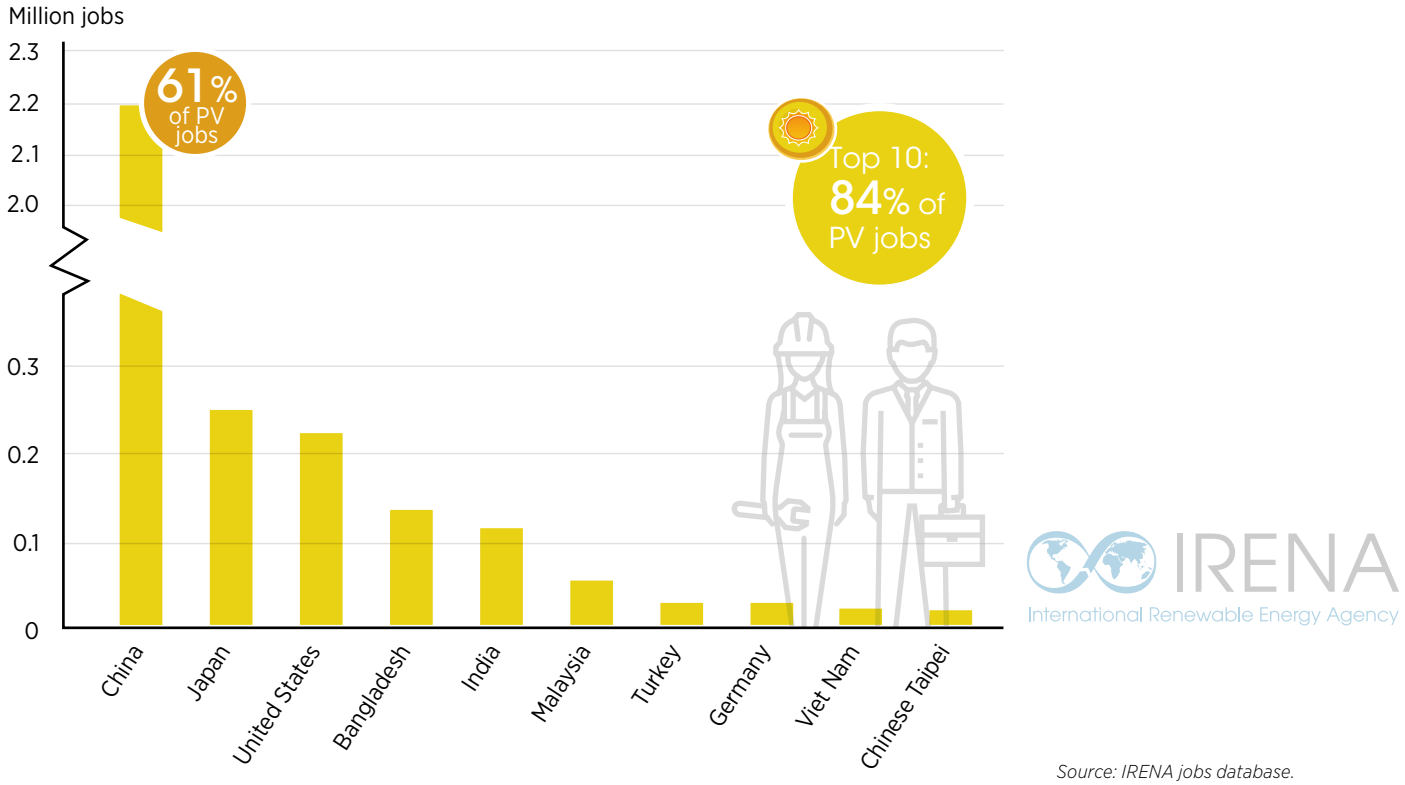
Solar PV employment in the European Union declined by about 5% to 90 800 jobs in 2017, reflecting a drop of more than 10% in installations[6] (EurObserv'ER, 2019). Policy uncertainties caused US employment to fall for a second year in 2018, to an estimated 225 000 jobs[7]. Japan's solar PV industry continues to face difficulties, including shortages of available land for deployment. Although the country's installation market is still one of the world's largest, additions in 2018 were below those of 2017. IRENA estimates that employment fell to 250 000 jobs in 2018.

5 The countries for which IRENA's database has solar PV employment estimates represent 464 GW of cumulative installations in 2018, or 97% of the global total. They represent 99.6% of the 94 GW of new installations in 2018.

6 The jobs data for the European Union and its member states throughout this report are for 2017, the most recent year for which such information is available. Details are at the EurObserv'ER website, https://www.eurobserv-er.org/category/all-annual-overview-barometers/.

7 This is an IRENA estimate based on the all-solar (PV, solar heating and cooling, and concentrated solar power) estimate of 242 300 jobs published by Solar Foundation, 2019.

FIGURE 6: **TOP 10 COUNTRIES IN SOLAR PV EMPLOYMENT**



Source: IRENA jobs database.

LIQUID BIOFUELS

The leading bioethanol producers all reached new output peaks in 2018. Biodiesel production also rose in many of these countries, but declined in Argentina and the European Union, and remained level in Australia, China, Malaysia and the Philippines[8]. Worldwide employment in biofuels is estimated at 2 million, an increase of 6% from 2017. Most of these jobs are generated in planting and harvesting of feedstock. Fuel-processing facilities tend to offer fewer jobs than does feedstock supply, but those jobs typically require higher technical skills and offer better pay.

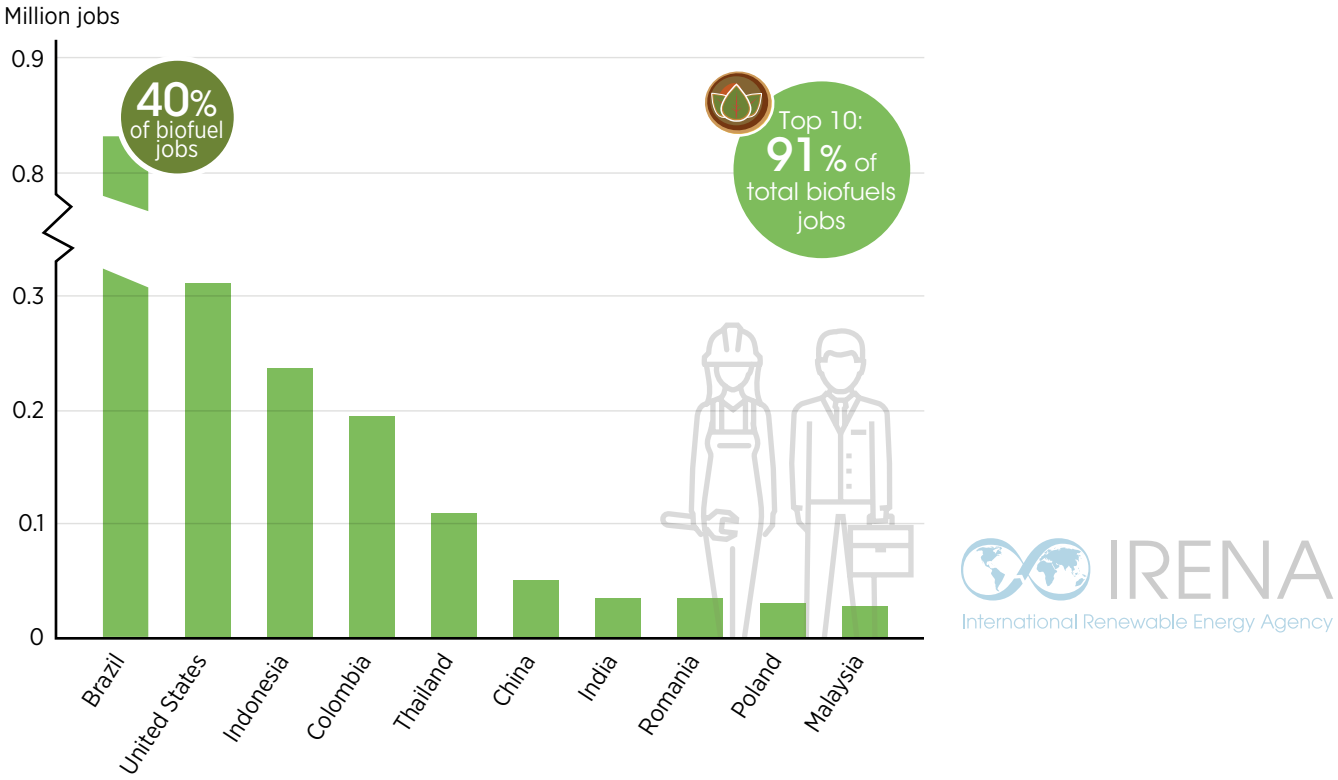
Annual changes in biofuels employment, notably, do not always equate to net job gains or losses. Oil palm, soybean, corn, and other feedstocks are used for a range of agricultural and commercial purposes outside the energy sector, and their end-use may therefore vary from year to year without people losing jobs. On the other hand, when people are displaced from their land by expanding biofuels plantations, agricultural livelihoods may be lost irretrievably.

The regional profile of biofuels employment differs considerably from that of the solar PV sector. Latin America accounts for half of all jobs worldwide, whereas Asia (principally labour-intensive Southeast Asian feedstock supply) accounts for 23%, North America for 16% and Europe for 10%. Figure 7 includes the top 10 countries, which together account for about 91% of global estimated employment.

With 832 000 jobs, Brazil has the world's largest liquid biofuel workforce. Record production drove up employment in the United States to more than

8 The 2018 production estimates are derived from the national biofuel reports published by the US Department of Agriculture's Foreign Agriculture Service, available at https://www.fas.usda.gov/commodities/biofuels.

FIGURE 7: **TOP 10 COUNTRIES FOR EMPLOYMENT IN LIQUID BIOFUELS**



Source: IRENA jobs database.

311 000 jobs. Biofuel employment in the European Union was estimated at 208 000 jobs in 2017, the most recent year for which data are available (EurObserv'ER, 2019).

For Southeast Asian producers, IRENA uses an employment-factor calculation that distinguishes labour requirements at plantations and smallholder farms. Backed by rising output (USDA-FAS, 2018a), Indonesia's biodiesel sector is estimated to employ 237 000 people in 2018, a 12% gain[9]. In Malaysia, the Philippines and Thailand, IRENA estimates a combined workforce of some 176 000 people[10].

Colombia's biofuel output rose to a new peak of about 1.1 billion litres in 2018 (USDA-FAS, 2018b). Employment factors based on data published by Federación Nacional de Biocombustibles de Colombia (FNBC, n.d.) suggest the number of people active in biofuels may have been as high as 202 000 jobs in 2018, but could include some part-time employment not converted to full-time equivalents.

WIND

Most of the wind industry's activity still occurs on land. The 540 GW of cumulative onshore capacity compares with about 23 GW in offshore projects (IRENA, 2019b). But offshore is gaining traction, receiving USD 25.7 billion of investments in 2018, or 20% of the wind total. For the first time, China led the way with offshore projects worth USD 11.4 billion. European projects attracted spending of USD 3.3 billion (Efstathiou, 2019).

Offshore wind farms tend to require more labour inputs than onshore projects. In addition to the construction, assembly, and deployment of new equipment such as platforms, they can leverage existing technical capacities and skills (IRENA, 2018) and use converted and upgraded existing infrastructure from the offshore oil and gas and shipping industries (Froese, 2018). Offshore wind development in northern Europe, for example, utilises the expertise of workboats that provide surveying, lifting and other services, and draws on the know-how of companies that build foundations for production platforms (O'Connell, 2018).

Together, onshore and offshore wind employ 1.16 million people worldwide, up 1% from 2017[11]. Most wind jobs are found in a small number of countries, although the concentration is less than in the solar PV sector. China accounts for 44% of the global total; the top five countries represent 75%. The regional picture is also more balanced than in the solar PV industry. Asia's 620 000 wind jobs make up about half the total, while Europe accounts for 28% and North America for 10%. Of the top 10 countries shown in Figure 8, five are European, three are Asian, and one each is from North and South America.

China remained the leader in new installations during 2018, adding 20 GW, of which 1.8 GW offshore (IRENA, 2019b). The country's total wind employment was estimated to hold steady at 510 000 jobs (CNREC, 2019), followed by Germany (140 800 jobs) and the

9 The calculation relies on revisions of an employment factor initially developed by APEC (2010). This factor is applied as a constant each year for smallholder production, which accounts for 45% of volume (WWF, 2012) and is more labour intensive than large-scale plantations. For plantations, IRENA applies an assumed "decline" factor of 3% per year as a proxy for rising labour productivity.

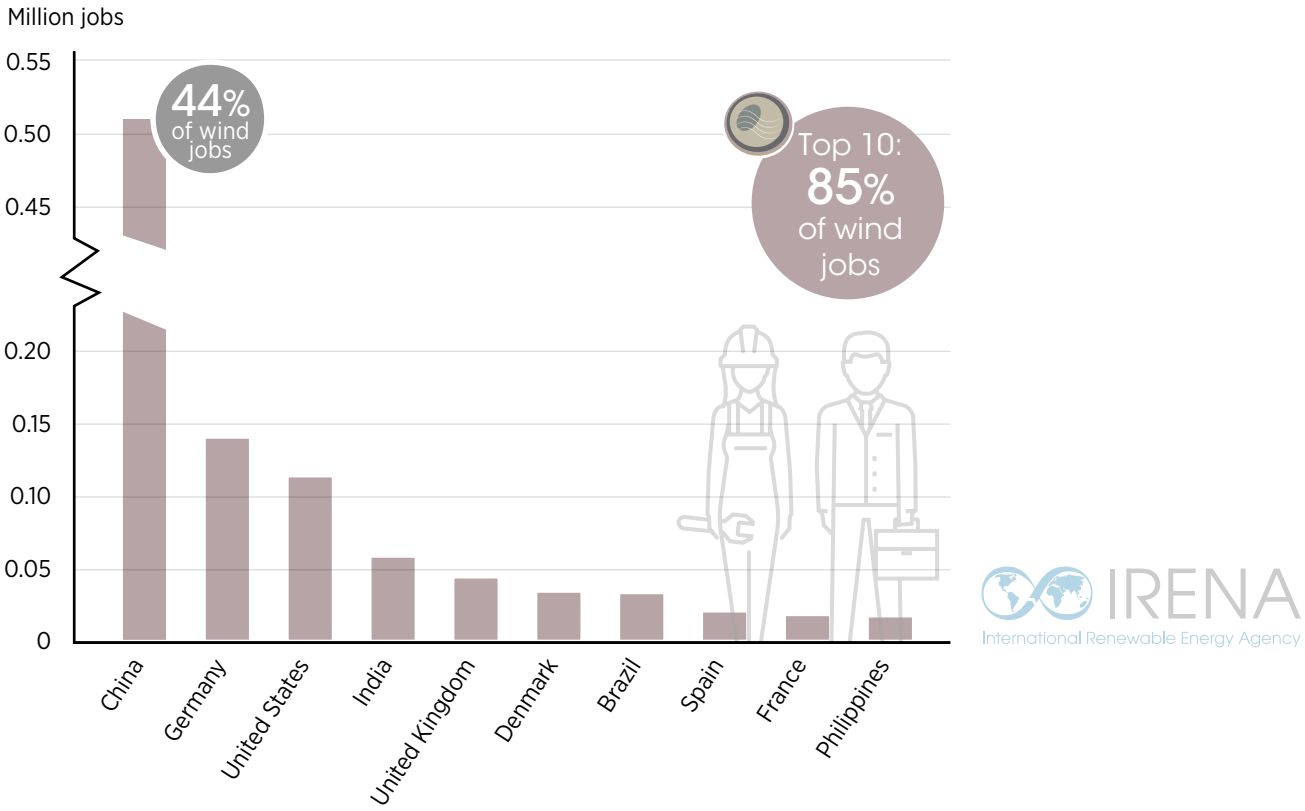
10 In Thailand, IRENA estimates 111 000 jobs. Smallholders have a 73% production share, an average of values reported by Termmahawong (2014) and by RSPO (2015). In Malaysia, smallholders account for roughly 35% of production (WWF, 2012). IRENA estimates 28 600 jobs in Malaysia, and 36 600 jobs in the Philippines. Analysing only the construction and operations of biofuels processing facilities, the Philippine government estimates direct employment of 2 328 jobs.

11 The countries for which IRENA's database has estimates of wind power employment represent 561 GW of cumulative installations, or 99.6% of the global total. They also cover 99.3% of the 49 GW of new installations in 2018.

United States, where wind employment grew 8% to a new peak of 114 000 jobs (AWEA, 2019).

Based on EurObserv'ER (2019) and national-level reports, IRENA estimates European employment at 314 200 jobs in 2017, the year with the latest available data. The continent's cumulative capacity reached 189 GW in 2018 (Wind Europe, 2019b). Europe is not only a leader in domestic installations but also holds a strong position in exports of turbines and foundations. In Denmark, export sales support the majority of wind manufacturing jobs (EurObserv'ER, 2019).

FIGURE 8: **TOP 10 COUNTRIES FOR WIND EMPLOYMENT**



Source: IRENA jobs database.

HYDROPOWER

Of all renewable energy technologies, hydropower continues to have the largest installed capacity. In 2018, it accounted for almost 50% of renewable energy in the world, but the share has declined as other renewables, in particular solar PV and wind, have grown faster than hydropower (Figure 9).

The analysis suggests that in 2018, over 2 million people were directly employed in the hydropower sector worldwide. Although the pace of new construction in key markets has slowed, the sector nonetheless experienced a growth of 3% over the previous year (Figure 10).

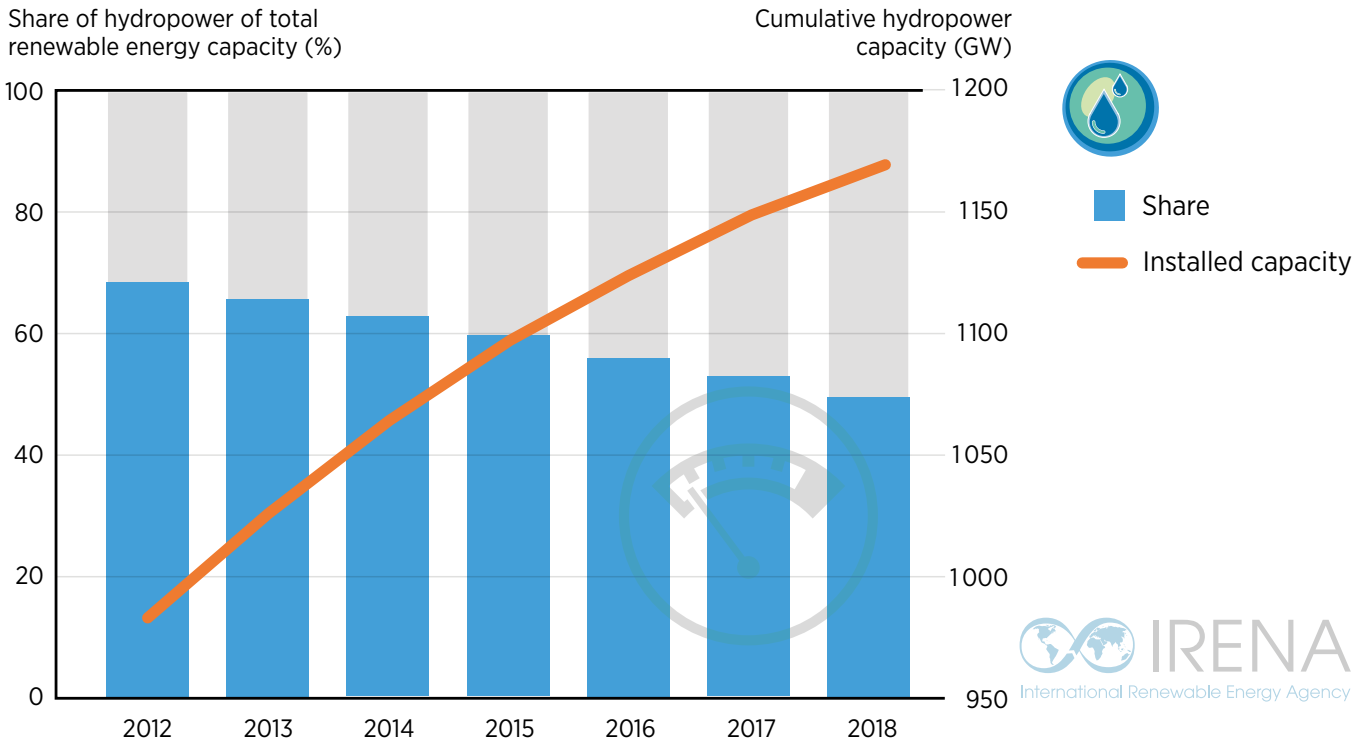
The distribution of employment across different segments of the value chain remains similar to previous years. More than 70% of the jobs are in operations and maintenance. Construction and installation represent 23% of the total; manufacturing is characterised by lower labour intensity and contributes just 5%.

Employment shares by country in 2018 provide interesting insights (Figure 11). India's labour-intensive

Previous editions of Renewable Energy and Jobs provided separate employment estimates for small and large hydropower. However, differentiating between them is difficult because of the scarcity of data and for lack of a universally agreed threshold (set variably by different countries at 10, 20, 30 and even 50 MW).

This edition combines both. The total is calculated by IRENA with the help of an econometric model based on capacity data, employment factors, and various national estimates and statistics.

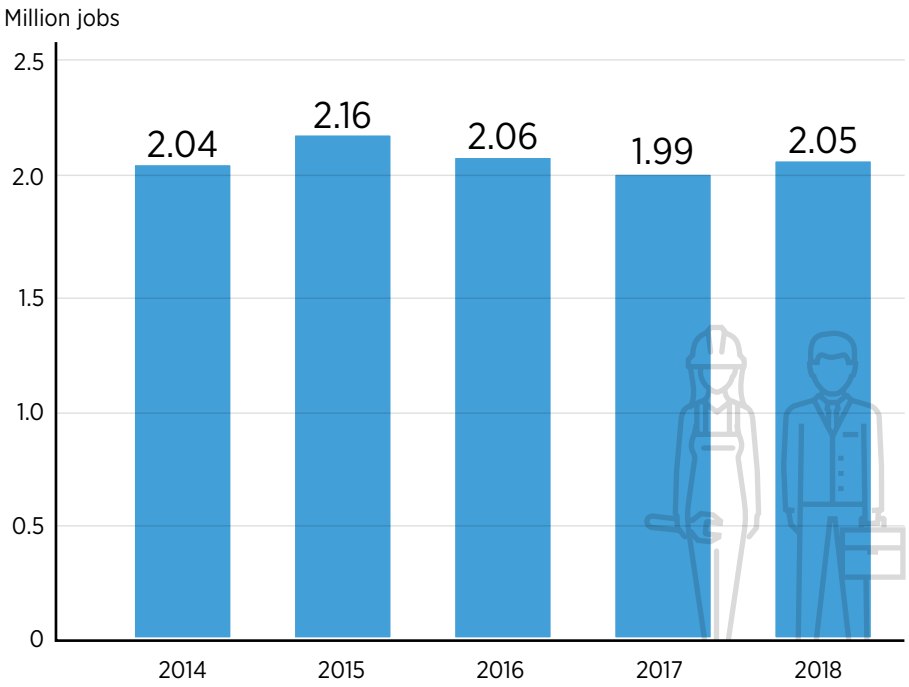
FIGURE 9: **HYDROPOWER CAPACITY, TOTAL AND RELATIVE TO ALL RENEWABLE ELECTRICITY CAPACITY, 2012-2018**



Source: IRENA, 2019b.

hydropower sector is the largest employer, accounting for 17% of the total, followed by China (15%) which experienced a decline in new installations. Brazil, where hydropower provides 77% of electricity supply (IRENA, 2019b), accounts for 10 % of the total. Other large players are Viet Nam (6%), Pakistan (5%), the European Union and the Russian Federation (4% each), and Iran (Islamic Republic of) and the United States (3% each).

FIGURE 10: **HYDROPOWER EMPLOYMENT, 2014-2018**

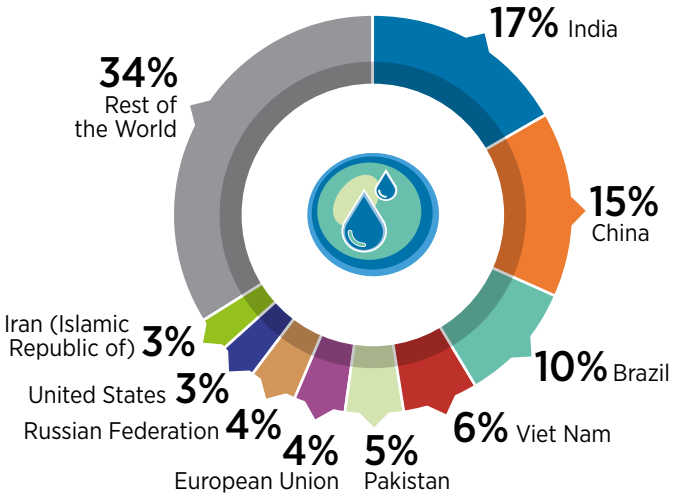


IRENA
International Renewable Energy Agency

Source: IRENA jobs database.

Note: Employment in hydropower is derived from a macroeconomic model and adjusted with national and regional data.

FIGURE 11: **HYDROPOWER EMPLOYMENT BY COUNTRY, 2018**



Source: IRENA jobs database.

SOLAR HEATING AND COOLING

Major solar heating and cooling markets, including China and Brazil, continued their downward trend in 2018, while India and several other markets showed increased activity (Malaviya 2019; Zhang 2019; Sother 2019). IRENA's estimates indicate that global employment in the sector declined to 801 400 jobs.

The top five countries account for 93% of all jobs. Asia is home to 711 000 jobs, 88% of the world total. Of the top 10, three countries are from Asia and three from Europe.

Estimates for China suggest that employment held steady in 2018 from the previous year (CNREC, 2019). With more than 70% of global installed capacity and a strong position in export markets, the country also remains dominant in employment. In cumulative terms, the US is the second largest national market, followed by Turkey, Germany, Brazil, India and Australia (Weiss and Spörk-Dür, 2018).

According to Eurobserv'ER (2019), the number of people working in the industry in the European Union declined from 29 000 in 2016 to 21 900 in 2017 (the latest year for which data are available)[12]. In the United States, employment was estimated by IRENA at 12 100 jobs in 2018.

Brazil and Turkey are among the key markets. The Brazilian market dropped by 1.1% in 2018, the third straight year of reductions (ABRASOL, 2019). IRENA's employment-factor-based estimates[13] suggest that the country's employment in this sector also fell slightly, to about 40 630 jobs. Turkey reported a major loss of employment, with the number of jobs down to just 8 660 in 2018 from 16 600 in 2017 (Akata, 2019).

India had the sixth-largest installed capacity in 2017. IRENA's employment-factor calculation suggests that the country may have employed some 20 700 people in 2018, when annual collector additions reached a new peak of almost 1.8 million square metres. However, since imports of Chinese-manufactured equipment have captured a growing share of the market, this calculation may over-estimate domestic jobs (Malaviya, 2019).

12 Eurobserv'ER does not differentiate between solar heating and cooling and concentrated solar power. National-level reports suggest a higher figure of 29 300 in 2017. For Spain, APPA (2018) puts employment at 6 200, lower than the 8 100 reported by Eurobserv'ER. For the United Kingdom, REA (2018) offers a much higher figure of about 9 500 jobs compared with the 200 jobs estimated by Eurobserv'ER.

13 IRENA uses an employment factor of one full-time job per 87 square metres (m^2) installed, as suggested by IEA SHCP (2016).

RENEWABLE ENERGY EMPLOYMENT: FOCUS ON ACCESS

Renewable energy plays an increasingly important role for improving energy access. Global renewable off-grid capacity more than doubled in the past decade, to 8.8 GW in 2018; off-grid solar PV expanded 10-fold, to 2.9 GW (IRENA, 2019b).

In South Asia, public sector programmes have had a strong role in improving energy access. By contrast, private sector "pay-as-you-go" (PAYG) business models predominate in Sub-Saharan Africa (see Box 2). Worldwide, investment in private off-grid ventures grew from USD 10 million in 2010 to USD 511.5 million in 2018, for a cumulative USD 1.7 billion. Nearly four fifths of the money went to Sub-Saharan Africa, compared with 15% to South Asia and 5% to Latin America. The top 10 firms, including Zola, M-KOPA, d.light, Mobisol, BBOXX, and others, secured two thirds of the total investment (St. John, 2019).

Information remains relatively sparse on the full employment impacts of off-grid renewable projects. Some 130 million off-grid solar lanterns, SHS, and other products had been sold worldwide by 2017 (Dalberg Advisors and Lighting Global, 2018). Through the use of sales data, survey information from close to 40 companies and in-depth interviews, GOGLA and Vivid Economics (2018) estimated direct off-grid solar employment in parts of Sub-Saharan Africa and in South Asia at 372 000 full-time equivalent jobs (see Figure 12). Some 56% of these jobs are located in rural areas and 27% are filled by women.

This employment estimate covers sales and distribution, installation and maintenance, and customer support, but excludes manufacturing and assembly. The jobs span a wide skills spectrum across sales, management, finance, logistics, engineering, technical support and software development. Cash-based transactions typically create more employment in the sales and distribution segments, whereas the PAYG model relies more on technical jobs such as software design,

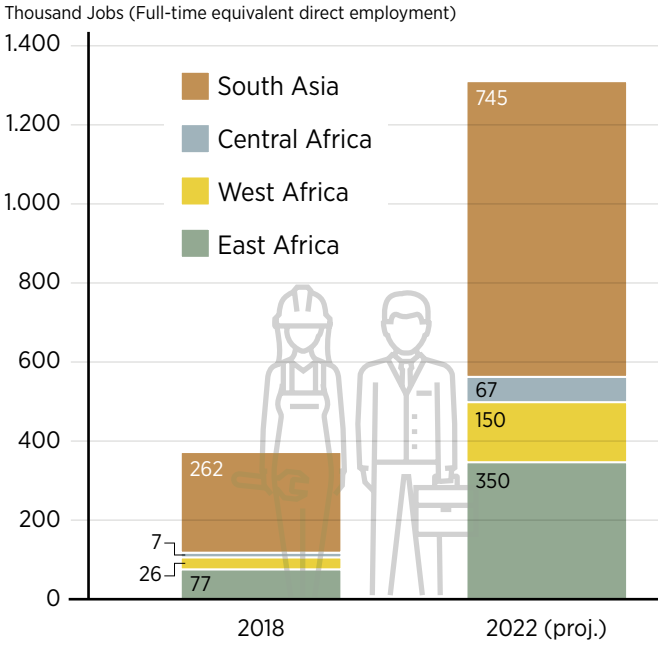
BOX 2. PAY AS YOU GO

Companies operating under the PAYG model are creating growing numbers of jobs (IRENA, 2016). A recent example is BBOXX's contract under the Democratic Republic of Congo's "Energie pour Tous" rural electrification initiative to provide energy access through solar home systems (SHS) and mini grids to 2.5 million people by 2020. This venture could create some 10 000 jobs (Tisheva, 2018).

However, the bankruptcy of Mobisol in April 2019 raises a cautionary note. Affordability is key, as prices and payment schedules are typically set to match households' cash flow. Customers make regular micropayments over a period of one, two or more years. Given the need for upfront financing, the model relies on continuous injections of capital for deploying additional systems.

Rising disposable incomes will grow the off-grid market. But PAYG companies need to adjust in the face of the rapidly falling costs of new solar products and growing competition from new market entrants (Dizard, 2019).

FIGURE 12: **DIRECT EMPLOYMENT IN OFF-GRID SOLAR, 2018 AND 2022**



Source: GOGLA and Vivid Economics, 2018.

logistics, and customer service. In general, wages in off-grid solar are substantially higher than the average wages in the countries where these jobs are created (Vivid Economics, 2019).

Additional analysis is needed to gain a more fine-grained understanding of the socio-economic impacts in different countries. In 2018, Power for All launched an annual jobs census on the decentralised renewable energy (DRE) sector in low-energy access countries (Power for All, 2018). It covers a wide range of solar technologies. Initially focused on Kenya, India and Nigeria, the geographic scope is to expand to 10 countries in 2019 and 25 the following year. The study surveys nearly 150 DRE organisations and includes focus group discussions with stakeholders from government, the skills and training sector, civil society, finance, and industry (Power for All, 2019).

The research analysis, to be released later in 2019, will yield valuable insights on total DRE employment, permanency of jobs and levels of compensation, current skill demand, recruitment challenges, and gender and youth representation. The study maps areas of indirect employment impacts in upstream activities such as equipment suppliers, or service providers such as training and education (Power for All, 2019).

Direct or indirect formal jobs are only the tip of the iceberg of the DRE sector's employment impact. In emerging economies, the informal sector is a major driver of the economy[14]. According to the survey and sector experts, companies selling SHS and solar lanterns are heavily dependent on a large network of informal workers such as field technicians and sales agents to distribute their products (Power for All, 2019).

Another key area of the DRE sector's employment impact is among rural DRE end-users. Newly acquired or improved energy access can benefit rural business performance, free up workers' time, encourage more studying hours for children, and create or enhance jobs as a result. Despite the lack of systematic reporting of induced jobs as an impact metric, 71% of the literature studying productive use impact found increased employment from energy access (Willcox *et al.*, 2015).

A 2018 study (GOGLA and Altai Consulting, 2018) found that 7% of households owning an SHS reported that ownership of such a system had enabled a family member to take on a new job. Among 44% of households, an SHS also unlocked more time for people to work, and 24% of households use the energy generated directly in a business or other income-generating activity.

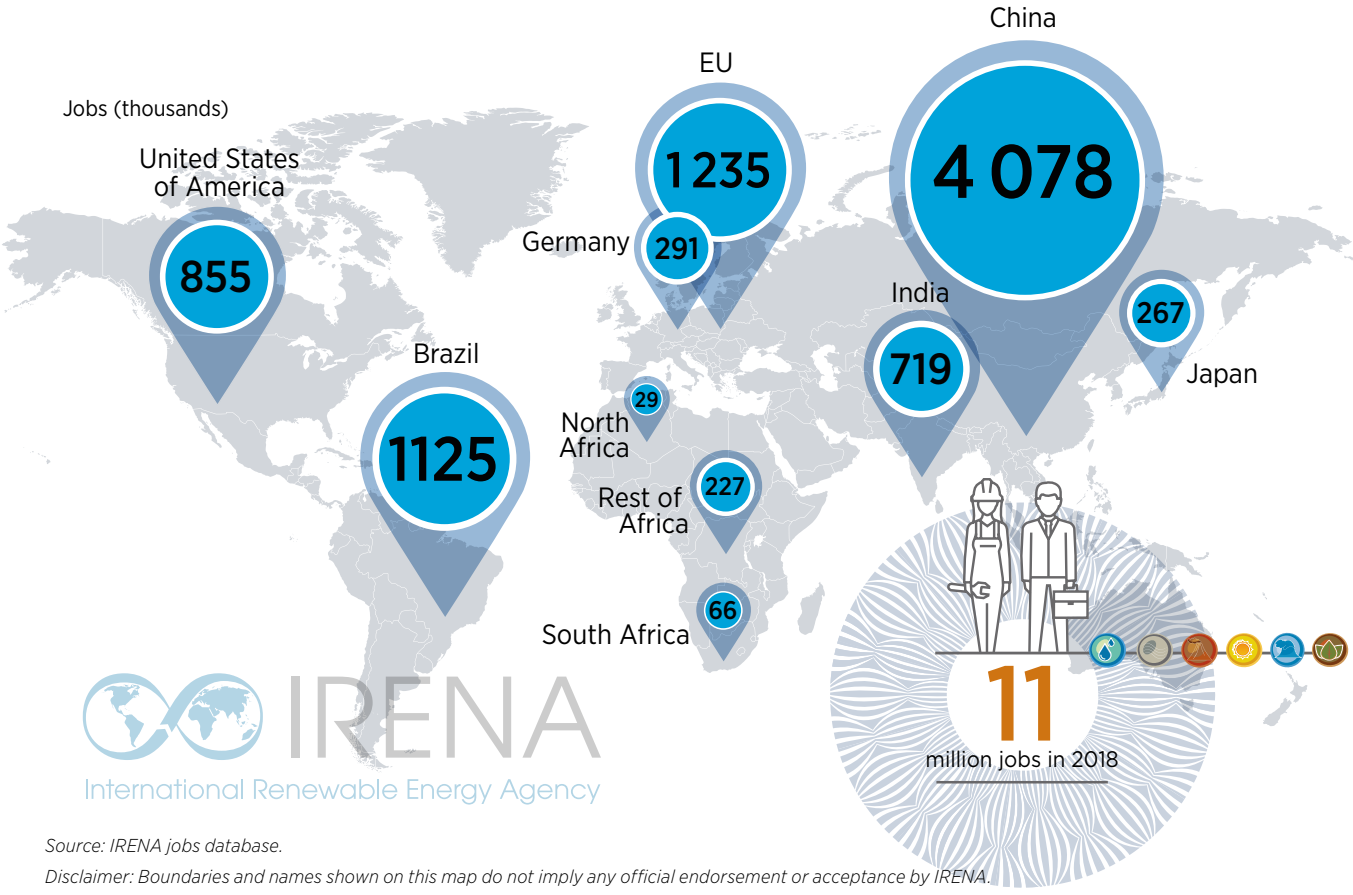
Most developing economies have ambitious electrification goals that necessitate rapid expansion of DRE solutions. Kenya's National Electrification Strategy established a goal of 100% electrification by 2022; in Nigeria, a total capacity of 8 GW of DRE solutions is needed to achieve its 30:30:30 Vision (World Bank, 2018b; Federal Republic of Nigeria, 2016). Based on an analysis of energy access policies, the Power for All study estimates future job creation potential and demand for talent. With a demand for more than two-thirds of its workforce skilled, the DRE workforce is facing a skills gap that is no longer a future threat but a challenge today.

14 In India, 88.2% of the employed population are informal workers, 82.7% in Kenya and 92.9% in Nigeria (ILO, 2018; World Bank, 2016).

RENEWABLE ENERGY EMPLOYMENT IN SELECTED COUNTRIES

This section presents key country-level trends and observations. It first discusses leading countries – China, Brazil, the United States, India, and members of the European Union (see Figure 13) – and then presents information on additional countries by region. Overall, the bulk of renewable energy employment is in Asian countries, which accounted for 60% of jobs in 2018.

FIGURE 13: **RENEWABLE ENERGY EMPLOYMENT IN SELECTED COUNTRIES**



Source: IRENA jobs database.

Disclaimer: Boundaries and names shown on this map do not imply any official endorsement or acceptance by IRENA.

LEADING MARKETS

CHINA

39% of global renewable energy jobs

- Solar PV: **2.2 million** jobs
- Solar Water Heating: **670 000** jobs
- Wind: **510 000** jobs

China remains the clear leader in renewable energy employment worldwide, accounting for 39% of the world's total. The country's total number of jobs, at 4.1 million, dipped below last year's level (CNREC, 2019).

In large part, this reflects the drop in solar PV from 2.216 million jobs to 2.194 million (CNREC, 2019). In May 2018, the government announced that it was suspending advantageous arrangements for utility-scale solar, imposing a cap on subsidised distributed solar, and reducing feed-in tariffs in response to continuous growth in solar subsidies. Subsidies had expanded in part because the authority that approves solar farms was delegated to the local level in 2013, making policy coordination difficult (Bin, 2018).

The country installed 43 GW of solar PV during 2018, 18% less than the previous year. Although rooftop PV saw gains, utility-scale deployment dropped significantly. Overall production of solar PV modules still grew by 21% in 2018 to 87 GW (Yuanyuan, 2019), but substantial overcapacities in the supply chain led to some factory closures and layoffs (Hutchins, 2018; Lin, 2018).

Offsetting lower domestic sales to a large extent, exports rose by 30%, to about 41 GW, during 2018. PV exports to emerging markets are being promoted through China's newly unveiled International Investment Alliance for Renewable Energy[15]. Chinese PV manufacturers are also increasing their global footprint, with production facilities in close to 20 countries (Yuanyuan, 2019).

Employment in the Chinese solar water heating industry held steady at 670 000 jobs. Following a sharp drop in new domestic capacity additions in 2014 from a peak of close to 45 GW_{th}, subsequent years saw more marginal reductions; in 2018, 24.8 GW_{th} was added (Zhang, 2019). However, these small reductions in market volume are not assumed to have translated into job losses. Changes in the product mix and greater efforts to integrate such technology into buildings have required additional labour inputs that offset volume reductions.

China's 2018 wind employment is estimated at 510 000 jobs, roughly the level of the previous year. Although the pace of new installations picked up (IRENA, 2019b), policy changes (such as more competitive bidding processes and subsidy cuts) may have discouraged companies from additional hiring. Meanwhile, the strong growth in the offshore segment did not fully translate into more domestic jobs, as imported components play a greater role than they do for onshore projects.

BRAZIL

Largest biofuels employer

- Biofuels: **832 000** jobs
- Solar Water Heating: **41 000** jobs
- Solar PV: **15 600** jobs
- Wind: **34 000** jobs

In **Brazil**, the biofuels sector remains the most important renewable energy employer. Output of fuel ethanol rose to record levels in 2018, and plans are to increase it further from 27.8 billion litres to 47.1 billion litres in 2028.

Biodiesel production of 5.4 billion litres also hit a record in 2018 (ABIOVE, 2019), driven by a rise in the biodiesel blend to 10% (USDA-FAS, 2018c). Output is expected to double to 11.1 billion litres over the next decade. To meet these targets, new ethanol and corn mills and soybean

15 The Alliance is a joint initiative by the National Development and Reform Commission, the National Energy Agency, the Ministry of Commerce and the Chinese Chamber of Commerce, and includes PV module manufacturer Jinko, and other Chinese PV and wind manufacturers, as well as companies specialising in engineering, planning and construction or operations and maintenance (Enkhardt, 2018).

oil extracting plants are needed; these could create an additional 1.4 million jobs over the coming decade (USDA-FAS, 2018c). Biodiesel employment rose to an estimated 257 000 jobs in 2018[16], while ongoing mechanisation of the feedstock supply chain caused bioethanol jobs to decline to about 575 000 jobs in 2017[17].

New additions to Brazil's wind power generating capacity ran to 2.1 GW in 2018, the fifth-largest amount worldwide (IRENA, 2019b), bringing cumulative capacity to 14.7 GW. More than 85% of this capacity is located in the northeast. The wind sector can bring industrial development and job creation to an area with comparatively low economic development, but skills deficits are an obstacle to local hiring (ABEEólica, 2019; Lucena and Lucena, 2019). IRENA estimates the country's wind workforce at close to 34 000 people[18]. Roughly one third of the jobs are in manufacturing, 42% in construction, and the remainder in operations and maintenance.

Trade statistics suggest that in 2014, domestic content in Brazil's wind energy manufacturing sector was about 89%[19] (CEMAC, 2017; CEMAC, n.d.). Brazil's national development bank BNDES offers subsidised loans if developers meet local content requirements of 65%. Over the years, this requirement has stimulated the emergence of a domestic supply chain of more than 300 companies[20] (Cuff, 2018; Ferreira, 2017). Among the foreign manufacturers investing in Brazil, LM Wind Power's blade facility in the Suape Port Complex of Pernambuco today employs nearly 900 people (Suape, n.d.; LM Wind Power, 2018).

New installations in Brazil's solar heating market declined by 1.1% in 2018, and employment is estimated to have declined, to 40 630 jobs (ABRASOL, 2018)[21].

But the country is ramping up activities in solar PV, installing 828 MW of large-scale capacity and 318 MW of distributed capacity during 2018. In operation since mid-2018, the country's 399 MW Pirapora solar complex in Minas Gerais is one of Latin America's largest, and uses domestic modules (Power Technology, 2018). IRENA's employment factor calculations suggest that Brazil presently has close to 15 600 jobs in solar PV, mostly in construction and installation. According to the industry group Associação Brasileira de Energia Solar Fotovoltaica, about 1 GW of capacity will likely be installed during 2019, and ABSOLAR projects that 15 000 new jobs could be created as a result (ABSOLAR, 2019a and 2019b).

16 The calculation is based on employment factors for different feedstocks (Da Cunha et al., 2014). The shares of feedstock raw materials are derived from ABIOVE (2019). Soybean oil accounts for the bulk (about 70%), followed by beef tallow (16%) and cotton seed and vegetable oils (14%).

17 Employment data are not yet available for 2018. In 2017, Brazil had around 217 000 workers in sugarcane cultivation and 158 000 in ethanol processing (MTE/RAIS, 2019). IRENA's employment estimate also includes an estimate of 200 000 indirect jobs in equipment manufacturing, though the figure is rough and dated.

18 This calculation is based on employment factors published by Simas and Pacca (2014).

19 Net imports were USD 254 million, out of total value-added of USD 2 400 million that year.

20 Domestic firms are well-established in tower production, but less so in turbine manufacturing, which is more technologically demanding (WEG, established in 2012, holds a small turbine market share; it acquired expertise through technology transfer and benefited from incentive programmes for local wind technology development, including an R&D programme by ANEEL (Agência Nacional de Energia Elétrica) and the Economic Subsidy for Innovation Programme operated by FINEP (Financiadora de Estudos e Projetos) (Ferreira, 2017).

21 This IRENA calculation of installation jobs is based on Brazilian market data and a solar heating and cooling employment factor. The estimate for manufacturing jobs is derived from an original 2013 estimate by Alencar (2013).

United States

Largest biofuels producer

Biofuels: **311 000** jobs

Solar: **242 000** jobs

Wind: **114 000** jobs

In the **United States**, the liquid biofuels, solar, and wind industries are the largest employers in the renewable energy field. US biodiesel output rose 16% to about 7 billion litres in 2018 (EIA, 2019b), and our estimations suggest that employment reached a new peak of 72 300 jobs. US ethanol production edged up slightly to 60.6 billion litres, with employment (direct and indirect) estimated at 238 500 jobs. In addition, economic modelling suggests that induced jobs, supported by income spent by employees in the bioethanol supply chain, number about 127 300 (Urbanchuk, 2019).

Solar experienced a second consecutive year of job loss, down to 242 300[22]. Two-thirds of these jobs are in installations and project development (mostly in the residential market). Manufacturing accounts for 14% (Solar Foundation, 2019). Domestic US module production has fluctuated over the years, but the vast majority of shipments are imported (EIA, 2019a).

Uncertainty surrounding US tariff policy delayed several utility-scale projects[23]. State-level policy changes in California and Massachusetts also dampened activity (Solar Foundation, 2019). New project announcements surged once the uncertainty over tariffs had lifted. Also, the Chinese government's decision in May to cut domestic solar incentives had the effect of reducing global demand for modules; the resulting over-supply lowered prices worldwide and counteracted the impact of the tariffs (Foehringer Merchant, 2018). As foreign suppliers continue to set up domestic manufacturing facilities (Roselund, 2019), tariffs become a less important factor.

Benefiting from the market stability afforded by the December 2015 extension of the Production Tax Credit (BNEF and BCSE, 2019), the US wind industry added about 7.6 GW during 2018, raising cumulative capacity to 96.4 GW or almost four times as much as a decade earlier (AWEA, 2019). Employment rose 8% in 2018 to 114 000 jobs (AWEA, 2019).

Listed in order of magnitude, employment in the construction and installation segment and in operations and maintenance is concentrated in Texas, Oklahoma, Iowa, California, and Kansas. Most manufacturing jobs are located in seven states: Ohio, Texas, Illinois, Pennsylvania, Wisconsin, North Carolina, and Michigan. Wind projects induce additional economic activity, and employment, through USD 761 million in annual state and local tax revenues and USD 289 million in land lease payments (AWEA, 2019).

22 This figure includes jobs in solar PV, solar heating and cooling, and concentrated solar power. A solar job is defined as one held by a worker spending at least 50% of his or her time on solar-related work. Census findings indicate that about 90% of these workers spend all of their time on such work. An additional 92 650 employees spent less than half their time on solar-related work. The 2018 edition of the Solar Jobs Census includes two job categories not covered in previous editions. The first concerns the territory of Puerto Rico, which has roughly 2 000 jobs. There are also 3 900 battery storage-related jobs in 2018. Adding these brings the US total to 248 200.

23 In April 2017, two solar manufacturers petitioned the U.S. International Trade Commission to impose tariffs on all imported crystalline silicon solar modules and cells. Tariffs were imposed in January 2018.

INDIA

719 000 jobs

Hydropower: **347 000** jobs

Solar PV: **115 000** jobs (Grid-connected)

Wind: **58 000** jobs

In **India** less utility-scale capacity was added in 2018 than in 2017, but rooftop installations expanded by 66%. By late 2018, cumulative capacity in the utility-scale segment was 24.4 GW, 3.8 GW in rooftop, and 0.8 GW in off-grid solar (Mercom India Research, 2019; Kenning, 2018b).

Auctions have pushed solar power tariffs to record lows. While this has generally led to higher installations in recent years, the resulting intense competitive pressure has led project developers to choose low-cost components over quality, sometimes cutting corners to win bids (Sushma, 2018). An analysis of six representative plants — conducted in collaboration with Indian government agencies — highlighted the importance of a well-trained (and by implication well-remunerated, thus higher-cost) workforce to guarantee installations and operations of sufficient quality (GIZ, PTB, and PIB, 2017).

India's employment in grid-connected solar PV, as estimated by IRENA using employment factors, increased to 115 000 jobs in 2018, a gain of more than 20 000. Jobs in off-grid solar applications cannot be calculated with precision but may well double total solar employment.

Seven of India's top 10 module suppliers are Chinese firms. Indian manufacturers cannot compete on cost, and many have limited access to low-cost loans. Imports, principally from China[24] and Malaysia but increasingly also from Thailand, Viet Nam, and Singapore[25], dominate the Indian market. In fiscal year 2018, domestic manufacturers had a market share of just 7% (Singh, 2019).

China is also becoming a leading force in the Indian inverter market. Replacing ABB (a Swiss-Swedish firm) and Japan's TMEIC as the leading suppliers, Huawei and Sungrow garnered a combined 31% share in 2017/18. Indian companies retain a much stronger foothold in solar project development, accounting for eight of the top 10 firms, and in the engineering, procurement and construction segment, where they represent six of the top 10 (Kenning, 2018a).

The Indian government has sought to craft workable policies in support of local manufacturing. Safeguard tariffs imposed in mid-2018 on imports from China and Malaysia were effectively offset by falling prices (Beetz, 2018b). A 10 GW manufacturing-linked tender by Solar Energy Corporation of India failed due to low tariff ceilings, safeguard duties, and other factors (Gupta, 2019). Viability gap funding of USD 1.2 billion for 12 GW worth of projects mandates that all modules and 40% of other components for grid-connected projects be domestically manufactured; for off-grid projects, the requirement was set at 70% (Gupta, 2018b; Verma Lal, 2019).

India came in fourth in wind generating capacity additions in 2018, but the pace of 2.2 GW was down substantially from 4.1 GW the previous year (GWEC, 2019). The sector is adjusting to the switch from preferential tariffs to an auction model (Kenning, 2018a). IRENA estimates that employment in the sector stood at 58 000 at the end of the year.

24 China accounted for 89% of imports in the last financial year. In 2017, India became China's largest foreign solar PV market with a 31% share of total exports (Upadhyay, 2018). The volume of Chinese sales in India rose almost eight-fold between 2014/15 and 2017/18, to about 9.8 GW (Verma Lal, 2018).

25 To sidestep trade barriers imposed by the European Union and the United States, Chinese solar companies set up manufacturing capacities in Southeast Asia: 12 GW in PV cells and 14 GW in modules (Upadhyay, 2019).

EUROPEAN UNION

1.2 million jobs

- Solid biomass: **387 000** jobs
- Wind: **314 000** jobs
- Solar PV: **96 000** jobs

In 2017, the most recent year for which data are available, the total number of renewable energy jobs in member countries of the **European Union** was estimated at 1.2 million (EurObserv'ER, 2019)[26]. This is virtually unchanged from the previous year but conceals fluctuations among technologies and countries. Five countries — Germany, Spain, France, the United Kingdom, and Italy — top the job rankings in most renewable energy sectors. Employment grew in liquid biofuels but declined in all other renewables industries.

Heat and electricity derived from solid biomass supported approximately 387 000 jobs in 2017. The biofuels sector employed about 230 000, up 12% from 2016. The countries with the largest agricultural supply chains have the bulk of the jobs, including Romania, Poland, Spain, France, and Hungary (EurObserv'ER, 2019).

IRENA estimates EU wind power employment in 2017 at about 314 200 jobs, down somewhat from the previous year[27]. The United Kingdom, Germany and Denmark are among the global leaders in this industry (including its offshore component, where Europe now has a cumulative capacity of 18.5 GW (Wind Europe, 2019a).

From just under 100 000 jobs, European solar PV employment dipped slightly to 95 600 in 2017, reflecting the diversification of the supply chain, rising labour productivity, and reduced domestic installation rates. Solar thermal employment[28] also contracted as a result of restrictive policies and regulations as well as competition from gas-fired heating and heat pumps, dropping from almost 40 000 jobs to 29 300.

A recent study (EY, 2017) concluded that greater ambition (raising the EU renewable energy target from 27% to 35%[29]) and proper policy support could raise PV employment to 175 000 jobs by 2021. Most of the added employment would be in installations and in operations and maintenance, which are more labour intensive than manufacturing.

Greater employment may also be possible in manufacturing (where wages tend to be higher), according to the newly-founded European Solar Manufacturing Council (ESMC, 2019). Meanwhile, a draft industrial policy was submitted by SolarPower Europe

to the European Commission. It envisages a 20% solar share in electricity usage; accelerating utility-scale deployment and installing at least 30 million solar roofs by 2030; boosting building-integration for PV; and pursuing solar-based sector coupling. It calls for 5 GW of solar PV module manufacturing capacity in Europe, supported by state aid and by easier access to financing and land (Beetz, 2018d). The association expects that such a policy could triple European solar employment to 300 000 jobs (SolarPower Europe, 2019).

26 The EU total, along with the estimates for individual renewable energy technologies, is based on EurObserv'ER (2019) and adjusted with national data in the cases of Spain (APPA, 2018) and the United Kingdom (REA, 2018). In some cases, notably, differences in econometric modelling methodologies used by the cited sources generate widely differing employment estimates.

27 EurObserv'ER (2019) offers a much higher estimate for Spain than APPA (2018): 37 200 jobs compared with 20 500. EurObserv'ER (2019) also presents a much higher figure for the United Kingdom than the Renewable Energy Association (2018): 69 900 jobs versus 44 100.

28 Including solar heating/cooling and concentrated solar power technologies.

29 In 2014, the European Union adopted a renewable energy target of at least 27% of final energy consumption by 2030, up from the previous 20% target for 2020. In mid-2018, a compromise was reached to raise the 2030 target to 32%, with an interim review set for 2023.

Germany has Europe's largest renewable energy workforce. Following some years of job loss, the number rose from 283 100 in 2016 to 290 700 in 2017 (Eurobserv'ER, 2019). Wind, solar PV, solid biomass and biogas gained, while other sectors still shed jobs. At 140800 jobs the wind industry represented almost half the country's total renewables workforce. Deviating from European trends, the solar PV workforce expanded slightly, due to higher domestic installations[30] (BSW, 2018) and export sales. Germany accounts for almost half of Europe's biogas employment, but the local market is stagnant and equipment manufacturers are relying more on export sales (Eurobserv'ER, 2019).

The United Kingdom and France are among Europe's leaders in renewables. In the **United Kingdom**, the Renewable Energy Association (REA, 2018) put total employment at 110 900 jobs[31] for 2016/17, a slight uptick. Close to 40% of all renewables jobs in the United Kingdom, filled by some 44 140 people, are in wind power.

Offshore wind projects are helping to revitalise coastal communities in the Humber and East Yorkshire regions, the Isle of Wight, and other areas. A GBP 310 million (USD 411 million) investment by Siemens Gamesa and ABP in turbine assembly and blade manufacturing has created about 1 000 direct and indirect jobs in Hull. The more than 300 jobs in blade manufacturing at an MHI Vestas Offshore Wind facility on the Isle of Wight are to expand to 380 (plus 720 indirect and induced jobs) (MVOW, 2018). A former oil-fired power plant has been converted into a paint and logistics facility for wind blades (Whitmarsh, 2019).

Roughly two-thirds of the UK's offshore wind supply chain are located overseas, principally in Denmark, Germany, the Netherlands and Belgium (Yang, 2019). The government's "Offshore Wind Sector Deal" seeks to raise the domestic share to 60% (Pantry, 2019). The Offshore Wind Industry Council projects that deploying up to 30 GW of capacity by 2030 could boost employment from 11 000 jobs to 27 000 (Whitmarsh, 2019). Women account for only 16% of the workforce, but the share can be doubled by 2030 (HM Government, 2019).

France is still a small player in the wind sector, but employment is expanding, supported by a diversified industrial base that encompasses more than a thousand small and large firms. According to the *Wind Observatory 2018*, France had a total of 17 100 direct and indirect jobs in the wind value chain, up 37% from 2014 (FEE and BearingPoint, 2018 and 2017). Most employment in 2017 was in engineering and construction (about 5 000) and in planning and design (4 900), followed by component manufacturing (3 800) and operations and maintenance (3 400). Manufacturing employment has remained unchanged since 2015, but other segments have grown strongly. The 3 GW of offshore capacity that is to be installed under the country's first tender could create nearly 10 000 more jobs, and the 2030 target of 15 GW could generate up to 30 000 jobs (Syndicat des Énergies Renouvelables, n.d.).

Specialising in different segments of the supply chain, several regions have benefited. Many head offices are in the Paris basin, while planning and design firms are primarily in the south (Occitanie). The northeast hosts half the installed generating capacity and thus many operations jobs. Most component manufacturing takes place in Pays de la Loire and Grand Est. The traditional industrial regions of Auvergne–Rhône-Alpes and Bourgogne–Franche-Comté are also beginning to take advantage of new opportunities. More than a dozen industry clusters have emerged around the country to facilitate innovation, knowledge-sharing and skill-building (FEE and BearingPoint, 2018).

30 In 2018, new grid-connected installations reached 2.96 GW, up from 1.76 GW the previous year (Schmela, 2019). However, this remains far below the peak levels achieved in the period 2009 to 2012, when about 7.5 GW were installed annually (BSW-Solar, 2016).

31 REA (2018) reports a total of about 9 800 jobs in the heat pump sector. However, including only ground source heat pumps (which most closely align with the renewable energy sector), employment is more likely to be about 1 700 jobs. The UK total employment estimate includes this smaller estimate.

OTHER COUNTRIES

In addition to the leaders in renewable energy manufacturing and deployment, some countries are expanding their presence, though others confront various challenges. A number of countries in East and Southeast Asia and in Oceania are rising to prominence in solar PV.

Japan's solar PV installations reached 55.5 GW in 2018, the second largest capacity after China. However, the pace of new installations declined for the third year in a row (IRENA, 2019b). The reasons include lower feed-in tariffs, land shortages and grid constraints (Bellini, 2019). Close to 300 solar firms have declared bankruptcy since 2015, with the number rising year after year (Teikoko Databank, 2019). IRENA estimates 2018 employment at some 250 000 jobs, a reduction of 22 000 from 2017[32]. A fresh impulse for larger installations and more jobs may come from the government's "Zero Energy Homes" policy, which requires new buildings to integrate solar PV and energy efficiency technologies by 2030 (Publicover, 2019).

The **Republic of Korea** employs about 7 500 people directly in the manufacturing and distribution of solar PV, slightly less than the previous year. Altogether the country puts renewable energy employment at 11 650 in 2018 (Korea Energy Agency, 2019).

Foreign direct investment has turned **Malaysia** into a major solar PV manufacturer for export markets. The Sustainable Energy Development Authority (SEDA, 2019) estimates that the number of people working in solar PV in 2018 rose to more than 54 300, from 40 300 jobs in 2017. Around 17 000 of these jobs are in component manufacturing[33]. For other renewables, SEDA reports that solid biomass and biogas employment declined slightly in 2018 to 9 400 jobs. IRENA's employment factor-based calculation yields an estimate of 28 600 jobs in the biodiesel supply chain. Altogether, IRENA estimates Malaysia's renewable energy workforce to have grown from 87 400 jobs in 2017 to 98 500 in 2018.

In contrast to Malaysia's on-going solar expansion, PV jobs in the **Philippines** declined from 34 000 in 2017 to just 20 800 in 2018. Wind power contributes close to 16 900 jobs, solid biomass more than 11 000, and geothermal power another 7 450 (Neri, 2019). IRENA estimates biofuels employment at 36 600 jobs, including informal jobs in the agricultural supply chain.

According to the **Australian** Bureau of Statistics (ABS, 2019), direct, full-time renewable energy employment stood at 17 740 jobs in the 2017/18 fiscal year, the highest level since 2011/12. Rooftop PV employed 8 240 people. Reflecting different methodologies and reporting periods, Green Energy Markets (2019) puts the total at 25 700 renewable energy jobs in 2018. This includes wind power employment of 10 100 people in 2018, almost 7 700 people in large-scale solar projects and 7 800 in rooftop solar.

32 In the absence of direct employment data, this calculation is based on the assumption that employment closely tracks the reduction in demand during 2018.

33 Including 520 jobs in silicon feedstock operations, 2 851 in ingot and wafer production, 9 660 in cell manufacturing, and 4 850 in module production (IEA-PVPS, 2018).

In the Americas, **Canada** has long had a footprint in hydropower and biomass, but wind is growing in importance, particularly in the provinces of Ontario and Quebec. Wind contributed 6% to national electricity in 2018 (CANWEA, 2018). In Quebec, the industry employs 5 000 full-time workers, including 1 000 in the city of Montreal (CANWEA, n.d.). Wind power has also helped to promote economic development in the Gaspé peninsula, where an industrial cluster of some 30 businesses comprises 1 000 direct jobs (Quebec Wind Energy Cluster, n.d.). Among them is a blade factory producing for the Canadian and US markets. Its expansion brought employment to 450 in 2018 (LM Wind Power, 2017). The province of Alberta has the third-largest installed capacity. A supply chain study found that 4.5 GW worth of new projects could result in about 14 900 job-years of employment by 2030, spread among services (6 634), manufacturing (5 472), construction (2 756), and operations and maintenance (714) (CANWEA, 2017).

In Latin America, Mexico, Chile and Argentina are among the largest actors after Brazil. Solar PV capacity in **Mexico** quadrupled in 2018 to reach 2.5 GW.

In **Argentina**, progress in adoption of renewable energy has been driven by legislation. Law 27191 (October 2015), which established a 2025 target of 20% renewables in total electricity consumption, led to the implementation of successful "Plan RenovAr" auctions and helped mobilise private sector participation. Moreover, the Renewable Energy Term Market (MATER) allows renewable energy generators and large users to trade renewable energy. As of March 2019, Argentina reports 9 614 people working in renewable energy, principally in construction. This includes wind energy, with 5 343 jobs (just over half of the total renewables workforce), and solar energy, with 2 555 jobs (Ministerio de Energía, 2019).

In the Middle East and North Africa region, **Turkey's** renewable energy workforce declined to about 62 000 people in 2018 (Akata, 2019) under the combined effects of broad economic dynamics, industry-specific developments and difficulties in securing project financing (Guler, 2019; Tsagas, 2019). In solar PV, employment fell as new installations dropped to 1.6 GW from 2.6 GW the previous year, when the end of feed-in tariff rates triggered a year-end rush of new construction (Kavruk, 2019). Turkey requires a 60% local share in module production, but many assembly plants are now closed (Tsagas, 2019).

If financing issues can be addressed, a wind power tender issued in late 2018 could lift employment. The new issue follows an initial 1 GW tender in 2017; the winning bid by Siemens Gamesa and its local partners, Kalyon Enerji and Turkerler Holding, included a commitment to set up a nacelle factory to satisfy a 65% local content requirement (O'Brian, 2018).

A number of large-scale wind and solar projects will increase the share of non-fossil energy and provide much-needed employment in **Egypt**. The first of a planned 41 plants of the Benban solar complex opened in early 2019 and employs some 650 people. Construction of the entire complex is estimated to require more than 10 000 workers, while some 4 000 people perform operations and maintenance activities (Reda, 2019).

A first employment estimate from **Iran (Islamic Republic of)** estimates that some 13 500 workers are employed in solar PV and 7 100 in the wind power sector (Bagheri, 2019).

In **Morocco**, about 100 people are employed at a new solar PV module factory in Al Hoceima (Bellini, 2018). Most employment to date has been generated at the Noor Ouarzazate solar facility (consisting of three concentrated solar power plants and one PV assembly) in the central Drâa-Tafilalet region. Working closely with ANAPEC (the National Agency for Employment and Capacity Promotion), the Moroccan Agency for Sustainable Energy has encouraged the use of local staff and materials. Commitments by project owners were higher than the required minimum (Stitou, 2019). On average, the share of Moroccan nationals at Noor runs to 70%, of which people from the local area represent somewhat less than half (see Table 1).

Lower-skilled jobs were more common in construction (46% of all construction jobs) than in operations (21%) (Stitou, 2019). The share of women is in the single digits. A 2017 study reported a high level of enthusiasm among women about the projects, but concluded that cultural norms, knowledge gaps about job options and requirements, and skill gaps were key obstacles to higher participation (World Bank, 2018a).

In Sub-Saharan Africa, direct employment in projects under **South Africa's** Renewable Energy Independent Power Producer Procurement Programme more than doubled from 17 800 job-years in 2014 to 36 500 by mid-2018. The majority of these are held by people from local communities. Some 85% of jobs were created in the construction phase, the remainder in operations.

The programme has led to the emergence of a small domestic wind and solar manufacturing industry (Govender, 2019). For example, a 300 MW solar PV module manufacturing facility set up by the Chinese company Seraphim created 100 direct jobs. That number is set to multiply as the plant expands (Beetz, 2018c). In the wind industry, tower manufacturing plants were set up to satisfy local content rules. But a foray into more complex blade-making did not succeed owing to high quality requirements and companies' perceptions that demand was insufficient to justify local production. Key nacelle components are imported.

TABLE 1. **EMPLOYMENT AT MOROCCO'S NOOR OUARZAZATE FACILITY**

		Employees on site				
	Local share commitment	Total	Moroccan employees		Local area employees	
	(percent)	*(number)*	*(number)*	*(percent of total)*	*(number)*	*(percent of total)*
Noor I	35	1 906	1 471	77	659	35
Noor II	40	4 063	2 723	67	927	23
Noor III	40	2 524	1 695	67	797	32
Noor IV	24	656	541	82	386	59
Combined	-	9 149	6 430	70	2 769	30

Source: Stitou, 2019.

THE WAY FORWARD

As the global energy transformation gathers pace, leaders and decision makers seek to maximise the social and economic benefits. Alongside decarbonisation and climate goals, countries need to create jobs and spur economic development.

IRENA's annual jobs reports (see Figure 14) have encouraged several governments, most recently Argentina's, to issue national estimates of renewable energy employment. Going forward, IRENA intends to work more closely with countries to collect knowledge on the renewable energy workforce worldwide.

IRENA will continue to estimate the number of jobs in the sector and analyse socio-economic impacts including skill levels, jobs and workplace quality, and the degree of gender equality. Policies to promote renewables must be accompanied by industrial and labour policies aimed at boosting supply chains, supporting local, national and regional economic development and providing technical and vocational training.

IRENA's Leveraging Local Capacities studies further assess skills and occupational requirements along the renewables value chain. Further, IRENA is modelling employment impacts in the REmap 2050 accelerated uptake scenario and continues to highlight ways to improve the gender balance in energy employment.

Gender is receiving greater national and international attention. Overcoming gender gaps in electricity access advances several Sustainable Development Goals. Access to clean, affordable, renewable energy also lowers barriers to women's market employment (IEA, IRENA, UNSD, WB, WHO, 2019).

IRENA noted links between SDG 7 (energy) and SDG 8 (jobs) for the UN's 2018 High-Level Political Forum (UN DESA, 2018). A new Energy and Jobs platform aims to foster information exchange and raise awareness among decision makers (see Box 3).

BOX 3. ENERGY AND JOBS PLATFORM

IIn 2019, IRENA initiated the Platform under the umbrella of the SDG7 Technical Advisory Group convened by the UN Department of Economic and Social Affairs. Partners include the International Labour Organization, the UN Industrial Development Organization, the World Bank, the European Commission, the Global Green Growth Institute, and Power for All.

Key goals include: Improving knowledge about the forces shaping renewable energy job creation; studying education and skills-training needs along the supply chain; evaluating opportunities to leverage domestic capacities; analysing policies and approaches to ensure a just transition; assessing the employment and livelihood opportunities linked to energy access; and highlighting the gender dimension.

FIGURE 14. **IRENA'S KNOWLEDGE BASE ON RENEWABLE ENERGY EMPLOYMENT**

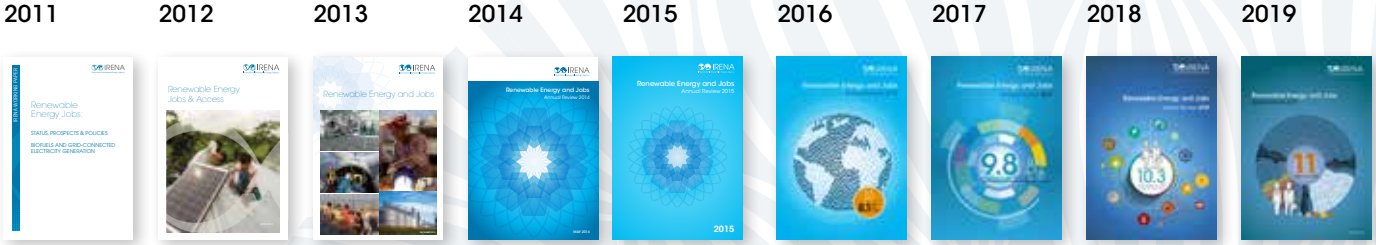


TABLE 2. **ESTIMATED DIRECT AND INDIRECT JOBS IN RENEWABLE ENERGY WORLDWIDE, BY INDUSTRY, 2017-18**

Thousand jobs	World	China	Brazil	United States	India	European Union[k]
Solar Photovoltaic	**3 605**[e]	2 194	15.6	225	115[k]	96
Liquid biofuels	**2 063**	51	832[g]	311[h]	35	208
Hydropower[c]	**2 054**	308	203	66.5	347	74
Wind power	**1 160**	510	34	114	58	314
Solar heating/ cooling	**801**	670	41	12	20.7	24[m]
Solid biomass[a,b]	**787**	186		79[i]	58	387
Biogas	**334**	145		7	85	67
Geothermal energy[a,d]	**94**	2.5		35[j]		23[d]
CSP	**34**	11		5		5
Total	**10 983**[f]	**4 078**	**1 125**	**855**	**719**	**1 235**

Source: IRENA jobs database.

Note: *Figures provided in the table are the result of a comprehensive review of primary national entities such as ministries and statistical agencies, and secondary data sources such as regional and global studies. This is an on-going effort to update and refine available knowledge. Totals may not add up due to rounding. Previous editions distinguished between small and large hydropower. Given changes in the available industry capacity data, this edition offers a single estimate for all hydropower facilities.*

Also in contrast to previous editions, this edition does not include country columns for Germany and Japan for lack of sufficiently up-to-date or detailed information.

a. Power and heat applications.
b. Traditional biomass is not included.
c. Direct jobs only.
d. Includes 8 600 ground-based heat pumps for EU countries.
e. Includes an estimate by GOGLA of 372 000 jobs in off-grid solar PV in South Asia and in East, West, and Central Africa. South Asia accounts for 262 000 of these jobs. IRENA estimates Bangladesh's solar PV employment at 135 000 jobs; most of the rest of the South Asian regional total is in India.
f. Includes 41 100 jobs in waste and 1 100 jobs in ocean energy, principally reflecting available employment estimates in the European Union, as well as 7 600 jobs not broken down by individual renewable energy technology.
g. About 217 000 jobs in sugarcane cultivation and 158 000 in ethanol processing in 2017, the most recent year available; also includes a rough estimate of 200 000 indirect jobs in equipment manufacturing, and 256 900 jobs in biodiesel in 2018.
h. Includes 238 500 jobs for ethanol and 72 300 jobs for biodiesel in 2018.
i. Based on employment factor calculations for biomass power.
j. Based on an IRENA employment-factor estimate. Separately, NASEO and EFI (2019) report direct geothermal power employment at just 8 526 in 2017-18.
k. Grid-connected solar PV only. Also see note e.
l. All European Union data are for 2017.
m. May include concentrated solar power for some countries.

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